The Bowron River Watershed: A Landscape Level Assessment of Post-Beetle Change in Stream Riparian Function

Lisa Nordin, David Maloney, John Rex, Phillip Krauskopf, Peter Tschaplinski and Dan Hogan

Mountain Pine Beetle working paper 2008-22

Natural Resources Canada, Canadian Forest Service,
Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5
(250) 363-0600 • cfs.nrcan.gc.ca/regions/pfc

Natural Resources Canada | Ressources naturelles Canada

Canada

The Bowron River Watershed: A Landscape Level Assessment of Post-Beetle Change in Stream Riparian Function

Lisa Nordin, David Maloney, John Rex, Phillip Krauskopf, Peter Tschaplinski and Dan Hogan

Mountain Pine Beetle working paper 2008-22

Ministry of Forests and Range, Northern Interior Forest Region,
5th Flr. 1011 4th Avenue, Prince George, BC V2L 3H9

MPBI Project # 7.03

Natural Resources Canada
Canadian Forest Service
Pacific Forestry Centre
506 West Burnside Road
Victoria BC V8Z 1M5
2009
© Her Majesty the Queen in Right of Canada 2009
Printed in Canada

Library and Archives Canada Cataloguing in Publication

The Bowron River watershed : a landscape level assessment of post-beetle change in stream riparian function / Lisa Nordin ... [et al.].

(Mountain pine beetle working paper 2008-22)
"MPBI Project #7.03."
Includes abstract in French.
Co-published by: Ministry of Forests and Range, Northern Interior Forest Region.
Includes bibliographical references:
ISBN 978-1-100-11742-3
Cat. no.: Fo143-3/2008-22E

1. Stream ecology--British Columbia--Bowron River Watershed. 2. Riparian ecology--British Columbia--Bowron River Watershed. 3. Logging--Environmental aspects--British Columbia--Bowron River Watershed. 4. Trees--Diseases and pests--Control--Environmental aspects--British Columbia--Bowron River Watershed. 5. Bowron River Watershed (B.C.)--Environmental conditions. I. Nordin, Lisa II. Pacific Forestry Centre III. Northern Interior Forest Region (B.C.) IV. Mountain Pine Beetle Initiative (Canada) V. Series: Mountain Pine Beetle Initiative working paper 2008-22

SB945 M78 B68 2009 577.68'30971182 C2009-980013-6

Abstract

Streams and riparian areas in the Bowron River watershed were assessed using the Routine Riparian Effectiveness Evaluation (RREE) to determine their level of ecological function 20-30 years after accelerated harvest activity. The RREE is a procedure that includes both stream and riparian indicators to assess the health and condition of a stream reach. Sites in heavily harvested sub-basins had lower overall evaluation scores than reference sites, mainly because of high failure rates of riparian indicators. Larger streams located lower in the sub-basin appeared to score slightly better than those in the upper basin and this is likely due to a larger riparian buffer at lower basin sites. A regeneration time of 20-30 years after clearcutting was determined to be insufficient for the recovery of riparian indicators to pre-harvest conditions. Variation among sites with respect to stream indicators appeared higher within the harvested and reference groups than between them, indicating that harvesting effects have diminished and natural variability is a stronger governing factor. The within-group variability was explained in part by differences in slope, channel width, coupling and soil erodibility. Recommendations for salvage logging best management practices are given based on observations of recovery from past harvesting activities and site specific characteristics.

Keywords: Beetle, Salvage logging, Properly functioning, Retention, Bowron, Routine Riparian Effectiveness Evaluation, Accelerated harvesting

Résumé

Des ruisseaux et des zones riveraines du bassin versant de la rivière Bowron ont été évalués à l'aide de l'évaluation de routine de l'efficacité de la gestion riveraine en vue de déterminer leur niveau de fonction écologique de 20 à 30 ans après une activité de récolte accélérée. L'évaluation de routine de l'efficacité de la gestion riveraine est une procédure qui inclut à la fois les indicateurs fluviaux et riverains pour évaluer la santé et l'état du passage d'une rivière. Les sites dans les bassins secondaires ayant fait l'objet d'une récolte intensive ont eu des résultats globaux inférieurs à ceux des sites de référence, principalement en raison des taux d'échec élevés des indicateurs riverains. Les cotes des ruisseaux plus grands situés dans le bassin secondaire inférieur semblent légèrement supérieures aux cotes de ceux du bassin supérieur, ce qui est probablement en raison d'une grande zone riveraine tampon aux sites inférieurs du bassin. Un temps de régénération de 20 à 30 ans après une coupe à blanc a été déterminé insuffisant pour la récupération des indicateurs riverains aux conditions d'avant la récolte. La variation entre les sites à l'égard des indicateurs fluviaux semble plus élevée dans les groupes où il y a eu une récolte et dans les groupes de référence qu'entre les groupes, ce qui semble indiquer que les effets de la récolte se sont atténués et que la variabilité naturelle est un facteur dominant important. La variabilité intragroupe a été expliquée partiellement par des différences de pente, de largeur du chenal, de couplage et d'érodabilité du sol. Les recommandations pour les pratiques exemplaires de gestion en matière de coupe de récupération sont formulées en fonction des observations sur la récupération à la suite d'activités de récolte antérieures, ainsi que des caractéristiques propres au site.

Mots-clés : Coléoptère, coupe de récupération, fonctionnement adéquat, rétention, Bowron, évaluation de routine de l'efficacité de la gestion riveraine, récolte accélérée

Table of Contents

1 Introduction 1
- 1.1 Harvesting in Riparian Areas 1
- 1.2 Properly Functioning Condition 1
- 1.3 Study Area Rationale 2
- 1.4 Study Objectives 2

2 Material and Methods 4
- 2.1 Study Area Description and Site Selection 4
- 2.2 The Routine Riparian Effectiveness Evaluation 5
- 2.3 Analysis 9

3 Results and Discussion 11
- 3.1 Site Observations 11
  - 3.1.1 Flooding 11
  - 3.1.2 Fines 12
- 3.2 Riparian and Stream Indicator Failures 13
  - 3.2.1 Upper-Basin Sites 13
  - 3.2.2 Lower-Basin Sites 14
- 3.3 Indicator Variability 15
- 3.4 Adjusting for Natural Variation 16
- 3.5 RREE and IWAP 18
- 3.6 Reference Site Failures 20

4 Conclusions and Recommendations 20

5 Summary 22

6 Acknowledgements 23

7 Literature Cited 24

8 Appendices 26

List of Tables

Table 1. Indicator failure rates for reference and harvested sites. 13
Table 2. Predictive physical attributes for indicator responses..... 15
Table 3. Measured attributes for specific indicator questions. 16
Table 4. Percent indicator failures after data adjustment for landscape and stream size variability. 18

List of Figures

Figure 1. Location of Bowron River watershed and IWAP riparian hazard ranking with 2007 RREE sample sites. 4
Figure 2. In-stream debris (McKenna Creek) and exposed banks (18-Mile Creek) from flooding. 11
Figure 3. Peak flows at the Bowron Box Canyon Hydrometric Station. 12
Figure 4. Fine sediments observed at stream margin and in stream bank at Lower Bowron reference sites..... 12
Figure 5. Cut stumps next to stream with poor riparian re-growth in Haggen Creek upper sub-basin 13
Figure 6. Negative relationship of shade and channel width at 11 non-harvested reference reaches..... 17
Figure 7. IWAP riparian hazard ranking vs 2007 effectiveness evaluation score. 19
Figure 8. RREE scores of total number of harvested and reference sites in upper and lower sub-basins..... 19

1 Introduction

1.1 Harvesting in Riparian Areas

Over the past few decades, riparian areas have gained recognition for their role in maintaining the structure and function of streams and the biota they support. Riparian vegetation slows precipitation runoff, regulates infiltration, stabilizes stream banks, controls bank microclimate and water temperature levels, and provides food and habitat for aquatic and terrestrial organisms. During the course of the past 30 years, British Columbia (BC) legislation has placed increasing restrictions on harvesting in the riparian zone, reflecting an increasing awareness of the importance of this area (see the BC Forest Act 1979, Forest Practices Code 1995, Forest and Range Practices Act 2002). The current Forest and Range Practices Act; however, still allows for the logging of riparian timber under specific circumstances. Riparian reserve zones can be harvested either as an approved activity in a forest stewardship plan (FSP) or under the Forest Planning and Practices Regulation (FPPR) s.51(f) for the purposes of sanitation or s.51(g) damage by insects as long as it will not have a material adverse impact on the riparian zone. This clause could potentially be implemented into most current harvesting plans in the BC interior as these forests have experienced a significant amount of damage by the mountain pine beetle (*Dendroctonus ponderosae*).

The current mountain pine beetle (MPB) epidemic in British Columbia is the largest recorded in North America and has been attributed in part to mild winters and fire suppression, both of which counter the natural regulation of the beetle population (Taylor and Carroll 2003; Wilson 2003). At the current rate of spread, it is estimated that 80% of the mature pine in BC will be dead by 2013 (Natural Resources Canada 2007). Accelerated harvesting has been the primary strategy to slow the spread of the beetle and recover the greatest economic value from the dead timber before it burns or decays. While upland areas contain the majority of beetle-kill timber, riparian forests also contain infected trees, providing rationalization for their harvesting. The question remains whether removal of this infected timber will result in future adverse impacts to the stream and affect the functioning condition of the riparian zone.

The purpose of this study is to evaluate the condition of streams and riparian zones in a watershed after a substantial amount of time has passed since logging. The Bowron River watershed was chosen based on past harvesting challenges similar to those associated with the current mountain pine beetle outbreak and a post-logging recovery time of 20-30 years. By evaluating a watershed in an advanced stage of recovery, we can identify impacts to the riparian system and use the information to consider whether adverse effects will be manifested as a result of compounding forest activities and hydrological response under present forest management practices. The evaluation also provides insight into which components recover first.

1.2 Properly Functioning Condition

Recent studies have investigated the influences of salvage logging on key hydrological parameters such as canopy interception (Buttle et al. 2000; Winkler et al. 2005) peak flows (Scherer 2001) and evapotranspiration (BC Ministry of Forests 2005). Yet to date there has been little investigation into harvesting effects and related hydrological responses on the functioning condition of a stream and its riparian area.

Properly functioning condition, as defined in the Forest and Range Practices Act, is the ability of a stream, river, wetland, or lake and its riparian area to: 1) withstand normal peak flood events without experiencing accelerated soil loss, channel movement or bank movement, 2) filter runoff, and 3) store and safely release water. These criteria form the backbone of the Routine Riparian Effectiveness Evaluation (RREE), a protocol used for determining anthropogenic impacts to a stream and the surrounding riparian habitat. The RREE evolved from BC's Forest and Range Evaluation Program (FREP) to meet resource stewardship monitoring objectives (Tripp et al. 2007). In addition to the above definition of properly functioning condition, the RREE includes the requirement for fish habitat in streams to be fully

connected, such that barriers to migration and specific habitat as a result of management activity are not present. The riparian habitat also must have an adequate root network, large woody debris (LWD) supply, and sufficient vegetation to provide shade and regulate bank microclimate. These requisites are products of suggested best management practices for logging different stream types in the Riparian Management Area Guidebook (BC Ministry of Forests 1995a). Although the RREE has been used frequently for recently harvested areas (< 3 years), until this study it had never been extensively applied to a watershed that experienced harvesting decades before.

1.3 Study Area Rationale

To determine the likelihood of long-term effects from salvage harvesting, the RREE procedure was used to assess present ecosystem function in drainages that were logged 20-30 years ago in the Bowron River watershed. In 1975, a blowdown event in the Bowron Lakes provincial park initiated a spruce beetle outbreak. In response to the rapid spread of the beetle, harvesting was accelerated and continued intensively throughout the late 1970s and into the mid-1980s before tapering in 1987 (Gerry Fraser, Canfor, Prince George, pers. comm.). One notable aftermath scene was a 50,000 ha clearcut which covered approximately 30% of the upper portion of the watershed (Beaudry 1997). Large portions of the middle and lower Bowron were also harvested and the primary transport routes still remain.

In the mid-1990s, Level 1 Interior Watershed Assessment Procedures (IWAP) were performed in the area as part of the Bowron Watershed Cumulative Impact Assessment. These procedures used descriptive data to generate impact indicators to synthesize into four hazard indexes including peak flow, surface erosion, landslide, and riparian buffer. (BC Ministry of Forests 1995b). A sample of the watershed assessment procedure report card can be found in Appendix I. The riparian buffer index assesses possible changes to the stability of the stream banks and large woody debris supply caused by the removal of streambank vegetation. The final index rankings were low, moderate and high impact and these were used to determine the location of our sample reaches during the field sampling design.

1.4 Study Objectives

The following objectives were set out at the planning stages of the project to meet the main goal of providing a landscape level assessment of post-beetle changes in stream and riparian function.

- To review all Bowron River watershed IWAPs to quantify the health of the sub-drainages immediately following harvesting.

  This objective was met in March 2007, and the results provided insight on potentially impacted areas. The information was used for site selection purposes.

- To utilize the routine riparian management effectiveness evaluation to assess the current condition of streams and riparian zones in the most heavily impacted sub-drainages as identified in the IWAPs.

  Sample streams in all high and moderate-risk sub-drainages were evaluated along with several in low-risk basins for reference.

- To use both evaluations to assess stream and riparian area recovery in the Bowron River watershed.

  Results of field evaluations, comparisons to IWAP data and conclusions are included in this report.

- Use results to provide recommendations to guide best management practices that will protect stream and riparian functions in MPB infested areas.

  Also contained in this publication are recommendations for future MPB practices.

- Transfer knowledge to licensees identifying the necessary riparian and stream characteristics to maintain their proper functioning condition.

  This was achieved by presenting preliminary results at the 2007 FORREX conference in Prince George, B.C. In addition, a website describing this project was developed and placed on the BC Ministry of Forests Fish-Forest Interaction website (http://www.for.gov.bc.ca/hre/ffip/Bowron.htm). Further, a summary of the project was published as Forest Extension Note #86 (Nordin, 2008) and a journal article was published (Nordin et al. 2008). Finally, a half-day workshop has been designed and is set to run in the spring of 2008 for licensees and other interested parties.

2 Material and Methods

2.1 Study Area Description and Site Selection

The Bowron River watershed is approximately 340,300 hectares in area and is located in the central interior of BC, about 50 km east of Prince George (Fig. 1a). The sub-boreal spruce (SBS) biogeoclimatic zone is dominant in the watershed with Engelmann Spruce and Subalpine Fir (ESSF) zones in higher elevations, and Interior Cedar Hemlock (ICH) in lower elevations (BC Ministry of Forests 2007). Overall, the area has a cool and continental climate characterized by moderately short, warm summers and long cold winters. Soils in the lower, middle and, to some extent, upper watershed are generally composed of fine-textured surficial materials, including glacial-lacustrine and sandy glacial-fluvial deposits. The watershed is primarily drained by the Bowron River, which runs north from the Bowron Lake Park to the Fraser River. The Bowron River and its tributaries are important for spawning sockeye (*Oncorhynchus nerka*) and chinook (*O. tshawytscha*) salmon. Populations of rainbow trout (*O. mykiss*), dolly varden (*Salvelinus malma*), mountain whitefish (*Prosopium williamsoni*), white sturgeon (*Acipenser transmontanus*), and burbot (*Lota lota*) also exist (BC Ministry of Environment 2007).

For the purpose of conducting the IWAPs in the 1990s, the large basin was sub-divided into 43 smaller basins and two residual areas. The IWAPs ranked these as low, moderate and high risk for each of the four previously discussed hazard indexes. This study includes all of the moderate and high risk sub-basins as identified by the riparian hazard index, as well as 11 low risk sites from the same region (Fig. 1b).

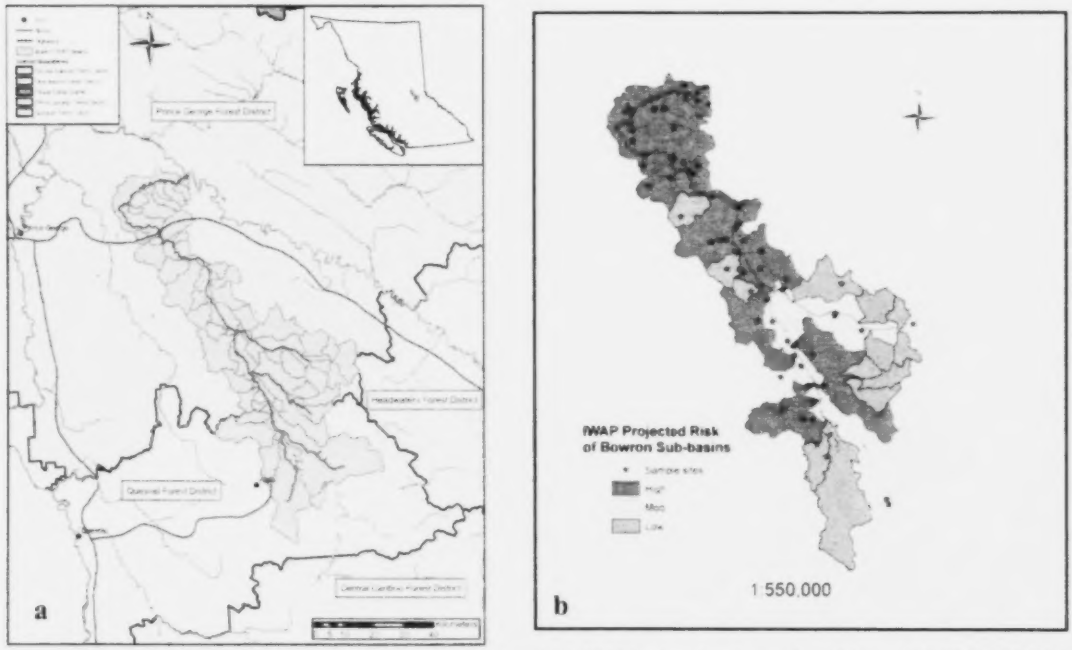


Figure 1. a) Location of Bowron River watershed and b) IWAP riparian hazard ranking with 2007 RREE sample sites.

Seventy reaches throughout the entire watershed were evaluated in total. This sample size includes two sites in each of the moderate and high risk sub-basins. The first was located at the lowest accessible reach in each of the drainages before the stream entered the Bowron River mainstem. This lower site was

selected to represent cumulative effects of the entire sub-drainage area; however, the riparian zone may or may not have been harvested at the sample reach. There were 30 lower treatment sites evaluated in total, consisting of two S1 streams (greater than 20 m channel width), twelve S2 streams (5-20 m), and sixteen S3 streams (1.5-5 m). There was no fish sampling performed and possible upstream perennial fish habitat was unconfirmed. Therefore, all streams were considered to be fish-bearing.

The other sample location within each sub-basin was at an upstream tributary where harvesting occurred within 60-80 m of the stream, depending on the stream size and classification. This is equivalent to double today's riparian management area (RMA). Although the salvage operation in the Bowron watershed occurred before the implementation of the Forest Practices Code and RMAs, this distance is suggested in the evaluation protocol and was followed to maintain consistency among sites. A riparian management area consists of a reserve zone where logging is restricted, and a management zone, which can be selectively logged to protect the reserve zone from the risk of windthrow. In the case of smaller streams with no reserve, the management zone can be logged but it is expected that enough vegetation will be left to protect the stream from extreme temperature fluctuations and channel bed/bank erosion (BC Ministry of Forests 1995a). Boundaries for RMAs vary with stream size; specifics can be found in Appendix II. The purpose of evaluating the upper sites was to show effects on a smaller scale. Twenty-nine upper sites were evaluated in total, including nineteen S3 and ten S4 streams. At the end of the field season, three sites that had been in the original design from relatively small sub-basins in the northern portion of the watershed had to be excluded because of accessibility limitations.

Most of the Bowron River watershed experienced harvesting to some extent, and thus it was difficult to locate controls in the same area. Evaluations for most of the eleven reference sites were done in low-risk sub-basins as identified in the IWAPs. In a few cases, upper-basin evaluations were done at tributaries in moderate or high risk sub-basins, but drained smaller areas that were not associated with logging or roads. For comparisons between the IWAP hazard rankings and field evaluations, all reference sites were given a risk ranking of low. Eleven reference sites were completed in total and consisted of four S2, six S3 and one S4 classified stream. Only three of these are lower-basin sites because of the lack of sub-drainages subject to minimal harvest and road activity.

2.2 The Routine Riparian Effectiveness Evaluation

The Routine Riparian Effectiveness Evaluation (RREE) used in this study was created as a monitoring strategy to meet the sustainable management goals set forth in the Forest and Range Practices Act (FRPA). The evaluation consists of a checklist with indicators and questions that give the user an assessment of the relative health and functionality of a stream and its riparian habitat. Each indicator category contains several attributes that need to be considered in order to answer the main question. The 15 main indicator questions used in the 2007 version of the protocol are listed and rationalized below (after Tripp et al. 2007). For ease of further discussion, they are grouped according to stream and riparian characteristics. Field site cards for the RREE can be found in Appendix III.

STREAM INDICATOR QUESTIONS

Question #1 • Is the channel bed undisturbed?

Disturbance such as aggradation or degradation can simplify a stream channel and reduce productive fish habitat. Impacts from logging can cause either too much sediment (i.e. from eroding roads, collapsing banks) or too little (traps caused by log jams or inappropriately sized culverts). Either situation will result in a less complex morphology characterized by a reduction in pools and a more uniform channel depth. Attributes that may lead to a failure for this indicator question include: mid-channel bars, sediment wedges, multiple channels and a lack of lateral bars.

Question #2 • Are the channel banks intact?

Forest harvesting can alter the amount and type of vegetation on stream banks, thereby reducing resistance to fluvial erosion. Disturbed banks contribute fine and/or coarse sediments to the stream. Fine sediments fill in void spaces between gravels and affect invertebrate diversity and fish spawning potential. Coarser sediments cause channel aggradation and can lead to a reduction of pools and possible dewatering. Attributes that may lead to a failure for this indicator question include: notable bank disturbance; the absence of deep-rooted vegetation; the lack of stable, undercut banks; and recently upturned root wads.

Question #3 • Are channel LWD processes intact?

LWD in the stream channel not only provides fish habitat, but also regulates sediment transfer and controls channel morphology. Impacts from harvesting can be gauged by examining the type, abundance and position of LWD accumulations. Attributes that may lead to a failure for this indicator question include: abundant post-harvest LWD, excessive accumulations which span the channel, parallel LWD in the stream, and removal of LWD by equipment or weather events.

Question #4 • Is the channel morphology intact?

Pools and riffles are important components of productive fish streams. The reduction of pools or riffles caused by harvesting activities will lead to diminished fish habitat. Attributes that may lead to a failure for this indicator question include: lack of pools, absence of deep pools (double riffle depth), and sediment texture homogeneity.

Question #5 • Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments?

In addition to logging, harvest-related structures can cause excessive aggradations, log jams and other obstructions to fish, which can compromise their use of important habitat. Roads contribute sediment to streams and those roads that do not have proper drainage systems can directly block off habitat. Improperly installed or inadequately sized culverts can constrict flow, create velocity barriers and/or insurmountable jumps for fish. Inadequately sized bridges can be a bottleneck for LWD and sediment movement. Built up sediment often leads to dewatering or downcutting, further impeding fish passage. Attributes that may lead to a failure for this indicator question include: the presence of recent blockages, downcutting, crossing structure related accumulations, dewatering and channel diversion.

Question #6 • Does the stream support a good diversity of fish cover attributes?

Fish cover diversity is indicative of an undisturbed stream with a well-developed riparian area. Although actual amounts of the cover can vary, it is rare for a properly functioning system to have less than five different types of cover. Attributes that may lead to a failure for this indicator question include: fewer than five of the following seven kinds of fish cover: deep pools, boulders, organic material, undercut banks, aquatic vegetation, overhanging vegetation and a stable mineral substrate with void spaces.

Question #7 • Does the amount of moss present in the substrate indicate a stable and productive system?

The relative abundance of a healthy growth of moss can be linked to fish and invertebrate productivity. The presence of moss in vigorous condition indicates moderate flows, clean water, a stable streambed, sufficient shading and adequate nutrient levels. If any of these qualities are altered, the abundance or health of moss will decline. Attributes that may lead to a failure for this indicator question include: absence or poor condition of moss.

Question #8 • Has the introduction of fine inorganic sediments been minimized?

Fine textured sediment can impact spawning and rearing habitat for fish by filling in the spaces between gravels and blanketing the substrate. Invertebrate habitat will also be affected and sensitive species (those with external gills) will be limited. Attributes that may lead to a failure for this indicator question include: abundance of fine sediment particles measuring less than 4 mm in diameter, single large areas of particularly soft patches of sediment, substrate embeddedness and the absence of sensitive invertebrates.

Question #9 • Does the stream support a diversity of aquatic invertebrates?

Invertebrates are sensitive to sand, silt, toxic compounds and pollutants, and are good indicators of a healthy stream with clean water. The number of invertebrates is not as important as the diversity of species because of the implication that a larger community requires a wider range of stable environmental conditions. When harvesting impacts cause large fluctuations in water temperature or turbidity, species numbers will decline until only those that can adapt persist. Attributes that may lead to a failure for this indicator question include low numbers of: sensitive invertebrate species, major invertebrate groups, insects, and total invertebrate species.

RIPARIAN INDICATOR QUESTIONS

Question #10 • Has the vegetation retained in the RMA been sufficiently protected from windthrow?

Windthrow in the riparian area over and above what is naturally expected is a direct sign of an ineffective management zone. The objective of reserve and management zones is to protect riparian areas from excessive windthrow and retain key wildlife attributes. Extensive windthrow in the riparian area can compromise the integrity of the stream bank, the functioning condition of the stream and the health of the aquatic and terrestrial biota. Attributes that may lead to a failure for this indicator question include: a greater incidence of post-treatment windthrow compared to natural windthow and the absence of functional wildlife trees.

Question #11 • Has the amount of bare, erodible ground or soil disturbance in the riparian area been minimized?

Soil disturbance includes both bare and disturbed (vegetated) ground. Exposed bare soil from harvesting is usually present on spur roads, skid trails, recent root wads and old landings. Bare soil can also result from recent hillslope slides and slumps. These areas of exposed soil are subject to erosion and contribute sediment to streams. The bare ground also reduces the capability to filter and regulate runoff

and promotes the establishment of disturbance-increaser plants. Disturbed ground is similar in that it is also compacted and sheds water rapidly, but it is not as vulnerable to erosion because it is vegetated. Disturbed ground can be the result of mechanical or animal disturbance and includes pugging, hummocking, vegetated deactivated roads and heavy equipment tracks, animal trails, and paved surfaces. Attributes that may lead to a failure for this indicator question include: both bare and disturbed ground within 10 m of the channel bank or otherwise hydrologically connected to the stream.

Question #12 • Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?

The root network is considered an essential criterion because it is the major contributor to bank stability. LWD is important not only for fish, but also to maintain channel form and function. Although harvesting may inadvertently cause an increase of woody debris to the stream in the short term, removing too much of the riparian vegetation will eventually cause a shortage of LWD. It can take several decades before a new plantation is able to provide woody contributions to the channel and for the majority of this duration, the stream will remain LWD poor. Attributes that may lead to a failure for this indicator question include: the absence of vegetation within 5 m for bank root network and insufficient woody debris supply.

Question #13 • Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?

Streamside vegetation is necessary to mitigate direct impacts of storm events as well as to moderate stream bank and water temperatures. Harvesting or intensive grazing can remove the protection provided by riparian vegetation and open the canopy to expose the stream to weather and temperature fluctuations. Attributes that may lead to a failure for this indicator question include: bare ground exposed to rain, insufficient shade, absence of moisture-loving plant species, and hot or dry soil.

Question #14 • Have the number of disturbance-increaser species or noxious weeds been limited to a satisfactory level?

Disturbance–increaser and invasive plant species often become established and thrive in disturbed areas. These types of plants are typically shallow-rooted species and often suppress the growth of natural deep-rooted vegetation. Once established, the shallow root systems are unable to provide adequate root networks for channel bank strength. In addition, most of these species lack sediment trapping capabilities and have low value as wildlife forage. Attributes that may lead to a failure for this indicator question include: abundance of disturbance-increaser plants and noxious weeds (species lists are provided in the protocol).

Question #15 • Is the riparian vegetation within the first 10 m from the edge of the stream generally characteristic of other healthy unmanaged riparian plant communities in the area?

A healthy riparian area is one that contains a diversity of trees, shrubs, herbaceous plants and ground cover (mosses, lichens) in vigorous condition and in various age classes. Intensively managed riparian areas may still contain trees but the structural diversity associated with a typical unmanaged forest is absent. Similarly, structural diversity will be diminished if heavy browse or grazing has reduced or eliminated the shrub or ground cover layer. Attributes that may lead to a failure for this indicator

question include: absence of major vegetation layers, poor health, the formation or recruitment of vegetation, and the occurrence of heavy browse or grazing.

Continuous and point measurements of specific attributes (as identified in Appendix III) were used in combination with subjective assessments to answer the indicator questions. Samples were taken along a homogeneous reach the greater of 100 m or 30 times the channel widths. The evaluation recognizes that different stream morphologies (step-pool, cascade-pool, riffle-pool, non-alluvial) should be assessed differently and thus there are different sets of attribute measurements for each group where applicable. Regardless of the difference in stream morphology, the indicator question remains the same, allowing for direct comparison of effectiveness across all groups. Attributes were recorded as a percentage of the reach length or riparian area with the exception of invertebrates and LWD accumulations, which were count values. These measurements were compared to specific threshold values that led to a "yes" or "no" answer (pass/fail) for the indicator question. By comparison, the LWD supply and riparian vigour/structure questions did not have measurements specific to them and indicator responses were based on field observations of the vegetation.

The number of "no" answers to the 15 main questions in the evaluation determined the condition of the site. No failures would represent a perfect stream and is unlikely due to storm events and other natural variability. Therefore, the evaluation allows for streams to have failures of some indicators and still remain properly functioning. The final four outcomes and the number of "no" answers allowed for each category were:

- Properly functioning condition (0-2)
- Properly functioning but at risk (3-4)
- Properly functioning at high risk (4-5)
- Not properly functioning (>6)

The procedure does not necessarily identify the causal reasons why a stream might be functional at risk or non-functional. Application of the procedure is meant to act as a trigger, identifying whether or not further investigation is needed and where questions regarding riparian/stream impacts need to be focused.

Field training in the proper application of the protocol was done at the start of the field season. Consultation and quality assurance checks were performed throughout the summer by Derek Tripp and Peter Tchaplinski, contributing authors of the RREE. For details on the procedure, please refer to Tripp et. al (2007).

In addition to the required data collected for the evaluation, site-specific characteristics were also recorded. Among these were channel width, buffer width, slope and coupling (a measurement of hillslope influence on material transfer to a stream). Additionally, the soil at each site was given an erodibility ranking of 1-3 based on field observations, soil maps and IWAP information.

2.3 Analysis

All statistical analysis was done using Systat version 11 (Systat Software Inc., Richmond, California). Prior to quantitative analysis, data was checked for normality and log (x +1) transformed when applicable to maintain homogeneity of variance. Chi-square tests were done to identify differences in failure rates between both harvested and reference sites. Site observations and comparison of binary data suggested a large amount of variability within both harvested and reference groups, indicating that site-specific characteristics added weight to the results. To further explore these potential influences, independent watershed characteristics were entered into a principle component analysis (PCA). The PCA is an unconstrained ordination that maximizes variation along successive orthogonal axes. This data

mining tool can help to identify independent variables that are possible predictors for the indicators. Buffer width, slope, channel width, soil erodibility, and coupling measurements explained enough of the variance to validate their use in further analysis. Next, a backward stepwise logistic regression (using alpha = 0.15 to remove) was performed with these same watershed characteristics against the binary (yes/no) indicator data. While the results from this analysis cannot be readily evaluated using conventional significance criteria in hypothesis tests, the procedure can prove useful for prediction and aid in understanding the variance within harvested and reference groups. Yet further analysis was necessary to adjust for any potential effects of non-harvest related variables.

The logistic regression detected several possible relationships and led to the examination of measured attributes that were used to answer the indicator questions. The continuous values for 15 attributes representing nine of the indicator questions were entered into a linear backward stepwise selection along with the previously mentioned watershed characteristics. Harvest date and buffer width were excluded so as to keep the adjustment to natural variability only. Results identified specific covariates for each indicator. To remove the effects of these covariates, a General Linear Model (GLM) was applied. The indicators were each analyzed individually as dependent variables with their own unique set of covariates. Sub-basin and upper/lower basin categories were also included so as to avoid problems with correlation. Adjusted means were produced, reflecting values that can be compared equally, despite site-specific differences in soil, slope, channel width or coupling. The adjusted data was compared to original values and any site that crossed the threshold from a fail to a pass was noted.

Original site cards were consulted and the indicator specific to the adjusted attribute was re-evaluated. A change in the original indicator answer depended on how the other attributes were assessed for that question. For example, shade is a measured attribute for bank microclimate, but because three other attributes have to be considered (see Section 2.2) and the threshold for a pass is three "yes" answers out of four, the adjustment of shade alone may or may not change the indicator from a fail to a pass.

After compilation of the adjusted data, Chi-square tests of homogeneity were performed on the adjusted indicator values to check for differences among harvested and reference groups. A one-way ANOVA was done on the final functionality scores to check for significant differences among sites grouped by their respective IWAP rankings.

3 Results and Discussion

3.1 Site Observations

3.1.1 Flooding

During the field season, a number of factors potentially influencing our results became apparent. The first consistent observation was stream-bank damage caused by high flows in both harvested and reference reaches. Signs of disturbance included fluvial sediment deposits on banks that were several feet above the stream level at the time of sampling, banks with exposed roots, and trees with bark and needles deposited in stream channels (Fig. 2).

Figure 2. In-stream debris (McKenna Creek) and exposed banks (18-Mile Creek) from flooding.

The 2007 peak flow (measured as a daily average) of 420 m^3/sec was ranked fourth highest out of thirty since recording began at the Bowron Box Canyon hydrometric station in 1977 (Lynne Campo, Water Survey of Canada, Vancouver, BC, pers. comm). This follows four years of peak flows that were below the average of 319 m^3/sec (Fig. 3). Although the 2007 peak flow was not remarkably high, it may have been sufficient to cause further damage to an already unstable system that had not recovered from previous high water levels. The 1990 record high of 580 m^3/sec was 82% higher than the 30 year average of peak flows and may have compromised the integrity of stream banks and reduced their ability to withstand smaller flood events in later years. Channel bank disturbance, moss and aquatic connectivity indicator failures were likely influenced by flooding; these failures will be discussed further.

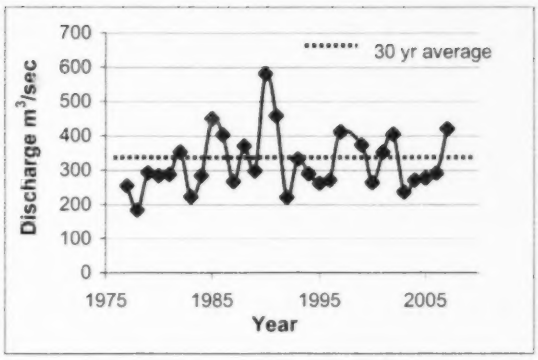


Figure 3. Peak flows at the Bowron Box Canyon Hydrometric Station.

3.1.2 Fines

Another frequently noted issue was the fine bed and bank material in many streams throughout the watershed. Glacial-lacustrine and glacial-fluvial material dominate the Bowron watershed and large amounts of clay and silts were seen at all sites, including reference reaches (Fig. 4). This natural sediment source primarily influenced the fine sediment indicator but also affected moss and fish cover, and will be discussed further in the results.

Figure 4. Fine sediments observed at stream margin and in stream bank at Lower Bowron reference sites. A stream with fine substrate such as this rarely displays macrophytes, boulders or void spaces for fish cover.

3.2 Riparian and Stream Indicator Failures

3.2.1 Upper-Basin Sites

Upper-basin harvested sites had higher average failure rates and scored more poorly on riparian indicators than reference sites (Table 1). This is not surprising as the upper-basin effect sites were within two RMAs of the stream and many were logged to the stream bank (Fig. 5). In most cases, regeneration of a logged riparian area was poor, even when planting was done in a timely manner following harvest. Managing the prompt growth of heavy brush after clearcutting was one challenge associated with returning the riparian area to a diverse, free growing community (Gerry Fraser, Canfor, Prince George, pers. comm.). Windthrow received a zero failure rate in the harvested group simply because there was no residual timber after riparian harvesting to evaluate.

Table 1. Indicator failure rates for reference (R) and harvested (H) sites.

	Upper-Basin Sites		Lower-Basin Sites	
Indicator	R	H	R	H
STREAM	%	%	%	%
Q1. Channel disturbance	13	7	33	17
Q2. Bank disturbance	50	48	67	73
Q3. In-stream LWD	0	86	33	87
Q4. Morphology	13	21	67	7
Q5. Connectivity	63	66	0	43
Q6. Fish cover	25	34	33	33
Q7. Moss	75	79	100	83
Q8. Fine sediment	50	41	0	50
Q9. Aquatic invertebrates	13	14	0	7
RIPARIAN				
Q10. Windthrow	0	0	0	3
Q11. Dist./ Bare ground	0	45	0	40
Q12. LWD supply	0	79	0	60
Q13. Shade/Microclim.	0	14	0	23
Q14. Weeds	0	3	0	7
Q15. Riparian vegetation	0	59	0	43
Average % Failure	20	40	22	38

Figure 5. Cut stumps next to stream with poor riparian re-growth in Haggen Creek upper sub-basin

Most of the failures of the harvested upper-site indicators can be attributed to logging the riparian zone. The protocol allows for some disturbance provided minimum thresholds for riparian criteria are met. However, in many cases the riparian vegetation was completely removed and regeneration was not sufficient to provide the stream with adequate shade or a satisfactory LWD supply. Not only was the riparian plantation too young to yield LWD but most of the trees were smaller in diameter than existing accumulations found in the channel, indicating any contribution from the stand would not be of sufficient size to be functional (Hyatt et al. 2004). Future woody debris supply at these reaches is almost certainly going to be scarce for decades, potentially affecting fish habitat (Mossop and Bradford 2004), distribution of sediments and coarse particulate organic matter (Anderson and Sedell 1979) channel morphology (Nakamura and Swanson 1993) and nutrient dynamics (Aumen et al. 1990). Another frequent indicator failure for harvested upper-sites addresses the question of riparian structure and diversity. A recovery time of less than 30 years after clearcutting did not allow for the regeneration of a riparian forest that was representative of an unmanaged forest as required by the protocol (Tripp et al. 2007).

In addition to the direct impacts of tree removal such as lack of shade, poor LWD supply and insufficient riparian structural diversity, the mechanism of harvest may have contributed to other riparian indicator failures. For example, the use of heavy equipment in the riparian zone likely resulted in an increase of disturbed ground and the propagation of noxious weeds and disturbance-increaser plants. Decades after harvest, even smaller sized streams did not show recovery of riparian indicators when logged to the stream-bank.

Stream indicators were less predictable than riparian indicators and there was no apparent trend in the failure rates between the harvested and reference groups. It is possible that, over time, harvesting effects as represented by stream indicators have diminished so that natural variability is the prevailing influence.

3.2.2 Lower-Basin Sites

Lower-basin harvested sites, representing cumulative effects of the entire sub-basin, scored slightly better overall than upper-basin sites. Reaches in the lower portion of the sub-basin were generally larger and frequently included buffer zones compared to reaches in the upper-basin. The average buffer width of lower-basin sites was 23.1 m compared to a 3.3 m average for upper sites. Although the presence of a larger buffer is likely related to lower failure rates of disturbed ground, LWD supply, and riparian vegetation structure compared to upper sites, the harvested lower sites still had a much higher failure rate of these indicators than the reference sites.

Cumulative effects from harvesting should be considered as a possible cause for failures of the fine sediment indicator in the lower effect sites. Lower reference reaches did not have any failures for fines whereas the harvested reaches failed 50% of the time. Stream densities for the sub-basins were comparable for both harvested and reference groups, indicating the quantitative pathway for the transportation of natural fines to the lowest portion of the sub-basins is similar. However, road densities in the harvested sub-basins averaged more than three times that of the non-harvested group and equivalent clear cut areas (ECAs) were more than double (see Appendix IV for sub-basin specifics). The amplified contribution of sediment to a stream as a result of roads concurs with Beschta (1978) who found suspended sediment production increased significantly in two Oregon watersheds after harvesting. This increase was attributed to mass soil erosion from roads.

Similar to the upper-basin sites, failure of the disturbed/bare ground indicator was higher in lower harvested reaches than reference reaches. Recently disturbed ground contributes more runoff and sediment to a stream due to its compact nature and exposed soil (Croke and Hairsine 2006; Wright et al. 1990) and consequently can affect bank and channel stability. This action can be compounded by steep slopes and easily erodible soils. While the effect may not detectable at a smaller scale, it can be magnified over the course of an average drainage area to result in a noticeable cumulative effect in lower-basin sites.

Like the upper-basin, failure rates for several of the stream indicators were analogous if not higher in the reference group compared to harvested sites. Further investigation into the mechanism behind these differences follows.

3.3 Indicator Variability

Variation in stream indicators seemed to be greater within harvested and reference groups than between them. There were significant differences between harvested and reference sites for in-stream LWD processes and LWD supply (both groups), and bare ground and riparian vegetation (upper-basin) ($\chi^2 > 3.84$, $P = 0.05$). Field observations at each site and a comparison of results within each group suggest a large amount of variability within each group for most of the stream indicators, and these appear to be dependent on the physical characteristics of the sample reach.

Site-specific characteristics including channel width, soil erodibility, slope, coupling, riparian buffer width and harvest date were key components to explaining variation within groups. These parameters were used in a PCA to investigate the appropriateness for their use in additional investigations. The PCA confirmed that 97% of the variance was explained using these watershed variables, which justifies their use in the following analysis.

All of the watershed parameters were entered into a backward-stepwise logistic regression along with indicator data to identify potential influences on the variability of the results. This analysis was done to investigate whether the outcome of a particular indicator question could theoretically be predicted by one or a combination of several watershed characteristics. Results suggest channel slope was the most common prediction variable for the indicators. Channel width, coupling and soil erodibility also contributed to prediction success (Table 2).

Not surprisingly, the two harvest-related variables--harvest date and buffer width--were predictors for indicators relating to in-stream woody debris, woody debris supply, aquatic connectivity (blockages), riparian vegetation and disturbed/bare ground. While this analysis is useful in identifying predictor variables, it does not allow for any adjustment because of the binary nature of the data.

Table 2. Predictive physical attributes for indicator responses (windthrow removed because of lack of data).

	Physical Attributes					
Indicator	Harvest Date	Buffer Width	Coupling	Channnel Width	Slope	Soil Erodibility
STREAM						
Channel disturbance				x	x	
Bank disturbance				x	x	x
In-stream LWD	x					
Morphology			x		x	
Connectivity	x			x		x
Fish Cover			x			x
Moss					x	
Fines	x	x		x	x	x
Aquatic Invertebrates				x		
RIPARIAN						
Dist./ Bare Ground	x					
LWD Supply		x			x	
Shade/Microclimate				x		
Weeds					x	
Riparian Vegetation		x				

3.4 Adjusting for Natural Variation

Data adjustment using a general linear model (GLM) on select measured attributes can compensate for natural variability. Each indicator consists of attributes that determine the outcome of the main question. In nine out of 15 indicator questions, one or more of the attributes are measured directly (Table 3). These measurements are continuous values and can vary in relation to natural watershed characteristics. One of the relationships recognized early in the field season was the negative correlation between shade and channel width (Fig. 6). Each attribute has a pass/fail threshold that may or may not vary with stream type (riffle-pool, cascade pool, step-pool, non-alluvial). For example, the threshold for channel bank disturbance differs among stream types, but adequate shade is set at 60% for all streams. Considering the threshold for shade, streams greater than around 6 m in this study would automatically fail the shade attribute regardless of any harvest activity. The GLM analysis removes the effect of this type of linear variability so the different sites can be compared equally.

Table 3. Measured attributes for specific indicator questions. HC = Hydrologically connected.

Indicator Question.	Measured Attribute
Q1. Channel disturbance	Mid-channel bars
	Multiple channels
	Lateral bars
Q2. Bank disturbance	Disturbed banks
	Undercut banks
	Root wads
Q4. Morphology	Pool length
Q6. Fish cover	Undercut banks
Q7. Moss	Moss abundance
Q8. Fine sediments	Fines abundance
Q9.Aquatic invertebrates	Species diversity
Q11. Dist/Bare ground	Bare soil within 10m
	HC bare soil
	Disturbed ground-10m
	HC disturbed ground
Q13. Shade/Microclim.	Shade

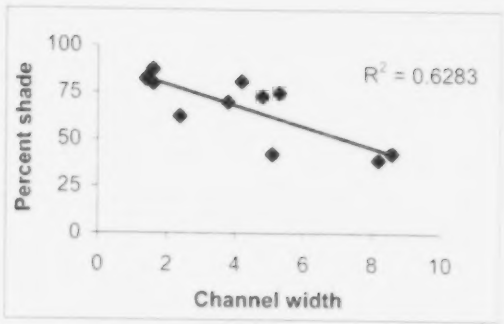


Figure 6. Negative relationship of shade and channel width at 11 non-harvested reference reaches.

The measured attributes are evaluated in combination with other characteristics that are assessed subjectively (see Appendix III for site cards). Six out of 15 indicators included attributes with no numerical data or data that would not improve the outcome through a linear adjustment. In order to maintain accuracy in the adjustment, natural covariates for each attribute were identified through a backward-stepwise linear selection using the same variables as in the logistic regression. Harvest date and buffer width were not included so as to keep the correction to natural variability only. Once appropriate covariates were identified for each measured attribute, the GLM was run to remove their effect and produce adjusted means for that attribute. The adjusted data was compared to original values and any sites that crossed the threshold from a fail to a pass after the adjustment were noted. Referral to original site cards was then made and the indicator specific to the adjusted attribute was re-evaluated.

The adjustment lowered failure rates in both the harvested and reference categories (Table. 4). The indicators for channel and bank disturbance, morphology, fish cover, moss, and aquatic invertebrates improved once natural variability among sites was accounted for. The values for the following indicators remained the same because they were either not improved or they did not have appropriate data for adjustment: In-stream LWD (Q3), Aquatic Connectivity (Q5), Fines (Q8), LWD Supply (Q12) and Riparian Vegetation (Q15). Weeds (Q14) and Windthrow (Q10) did not include enough data for a strong model and were also not changed. Bare soil within 10 m was the only adjusted attribute for the disturbed/bare ground indicator as harvest date was the only covariate identified for the other attributes in this category. The identification of harvest date as a relevant predictor variable indicates recovery of disturbed/bare ground over time.

Table 4. Percent indicator failures after data adjustment for landscape and stream size variability.

	Upper-Basin Sites		Lower-Basin Sites	
Indicator	R	H	R	H
	%	%	%	%
STREAM				
Q1. Channel disturbance	0	3	0	3
Q2. Bank disturbance	50	45	33	53
Q3. In-stream LWD	0	86	33	87
Q4. Morphology	0	30	33	0
Q5. Connectivity	63	66	0	43
Q6. Fish cover	25	34	33	23
Q7. Moss	50	48	66	47
Q8. Fine sediment	50	41	0	50
Q9. Aquatic invertebrates	0	14	0	3
RIPARIAN				
Q10. Windthrow	0	0	0	3
Q11. Dist./ Bare ground	0	45	0	40
Q12. LWD supply	0	79	0	60
Q13. Shade/Microclim.	0	14	0	23
Q14. Weeds	0	3	0	7
Q15. Riparian vegetation	0	59	0	43
Average % Failure	16	38	13	33

After the adjustment, the upper and lower harvested groups still did not display consistently higher failure rates of stream indicators than the reference groups. Several of the harvested group indicators appeared to have higher failure rates, but this difference was only significant in the case of in-stream LWD.

The LWD indicator failed 86% and 87% of the time in upper and lower reaches respectively. The reason for these failures was not because there was a lack of LWD, but, rather, the contribution was a result of harvesting as signified by mechanically cut ends. This input could, in turn, lead to failures of other indicators. For example, an excess of LWD leads to a higher occurrence of log jams, which can cause changes to stream bed texture, thereby contributing to channel bed and bank disturbance (Haschenburger and Rice 2004; Hogan et al. 1998).

High flows probably contributed to failures of several indicators in both the harvested and reference groups. Channel banks exhibited the most obvious disturbance, surpassing the protocol threshold in five out of the 11 reference sites (four from the upper-basin and one from the lower). Moss was another indicator that was likely affected by high flows, judging by the evidence of scouring. Failures for aquatic connectivity could also be associated with flooding as jams in smaller channels could be linked to newly deposited accumulations of both upstream debris and recent deposits from bank erosion. Lower reference sites did not restrict the flow of naturally deposited LWD and did not have any blockages. This is in comparison to lower harvested sites which had significant jams 43% of the time. These blockages consisted of mostly larger, older wood which were likely remnants from previous years when harvesting practices included concessions for leaving logging related debris in stream channels.

3.5 RREE and IWAP

Once all of the indicator results were tabulated, the average RREE score for each category was compared to the IWAP riparian hazard ranking. Sites were grouped by their respective IWAP hazard

ranking and then RREE scores were averaged for those groups (0=not properly functioning to 3=properly functioning). Reference sites representing the low-risk group scored better overall (i.e. passed for more indicators) than the other two groups despite some failure in stream indicators (Fig. 7). The low-risk group's scores were significantly higher compared to scores in the moderate-risk and high-risk groups in the upper-basin category (ANOVA $P < 0.05$). There was no significant difference between the moderate and high-risk categories, but this could be because there were three IWAP risk categories and four RREE outcomes, which results in some overlap. There were also no significant differences among the lower sites, which could be due to the large variance associated with small sample size.

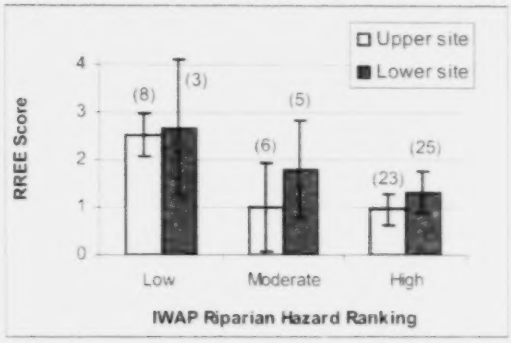
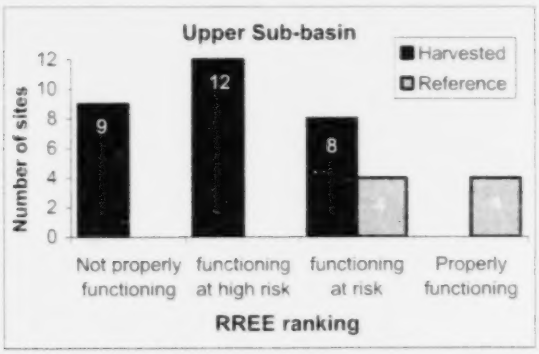
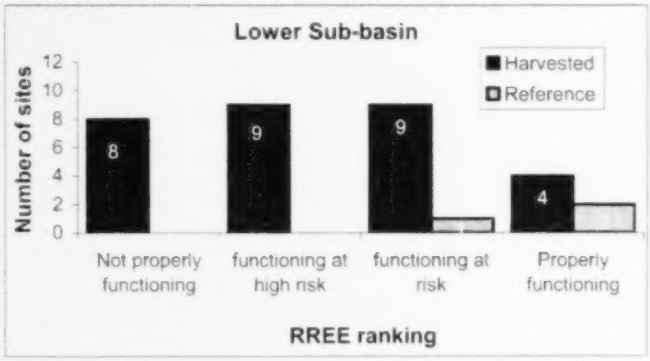


Figure 7. IWAP riparian hazard ranking vs 2007 effectiveness evaluation score. 0 = not properly functioning, 1 = functioning at high risk, 2 = functioning at risk, 3 = properly functioning. Error bars = 95% CI (n).

Harvested sub-basins had a lower percentage of properly functioning streams than the reference sites in both the upper and lower basins. None of the sites in the upper basin and only four sites in the lower basin were scored as properly functioning, representing 13% of the lower-basin sample size (Fig. 8). Three of these four sites had a riparian area of 75 m or more on both sides and the remaining site was only logged to the stream bank on one side, lending credibility to the inference that buffers are critical. All other harvested streams ranged from functioning at risk to not properly functioning.



a)



b)

Figure 8. RREE scores of total number of harvested and reference sites in a) upper and b) lower sub-basins.

3.6 Reference Site Failures

Reference sites scored as either properly functioning or functioning at risk (Fig. 8). Four sites out of eight and one out of three sites were at risk, representing 50% and 33% of the sample size in the upper and lower basins respectively. The lower site received failures for banks that were not intact, stream morphology (not enough pools) and absence of moss. Three out of the four upper sites also had failures for the moss and intact bank indicators. The remaining failures among upper basin sites were shared among indicators for fines, fish cover and aquatic connectivity.

Reference site failures in this study can be attributed to flooding and natural site characteristics. High water levels may be responsible for the absence of moss as evidenced by scouring, occurrence of log-jams in the upper-basin sites, and in-stream LWD failures in the lower sites. Where harvested lower sites failed for the LWD indicator 86% of the time because most of the contributions were the result of logging, the reference sites failed simply because the larger streams lacked LWD. Bilby and Ward (1989) found that although the average diameter and length of in-stream wood increased as channel width increased, the frequency of woody debris naturally decreased with stream size. Considering this, it is likely that the lack of debris in the lower-basin reference channels is the result of a combination of spring peak flow effects on naturally low numbers of LWD and, consequently, the recent removal of any moveable in-stream pieces.

Upper-basin reference sites had a 50% failure rate for fines. The variability of the results associated with site-specific characteristics suggests that the outcome of this indicator is dependent on the parent material of the bed and bank in each sample reach. A naturally occurring fine substrate will also lead to failures in fish cover because of the lack of boulders, interstitial spaces for juvenile fish and poor substrate for the growth of macrophytes. Poor values for these three attributes alone are cause for failure of the fish cover indicator. Failures for moss in areas that had predominantly fine sediments were common because of the unsuitable substrate for moss growth.

The reference streams had unexpected failures for the morphology indicator. Most of the failures were due to lack of pools. While this could be attributed to the natural morphology representative of the watershed, it doesn't explain why harvested sites fared better. However, as noted previously, harvested sites received a higher failure rate for the LWD indicator because there was still a large amount of logging-related debris in the streams and, consequently, over the course of 20-30 years this could have created more pools. LWD has been linked to the formation of pools in other studies and remains a strong contributing factor to channel morphology (Hyatt et al. 2004; Mossop and Bradford 2004; Nakamura and Swanson 1993; Roni and Quinn 2001).

The RREE is an evaluation of functioning condition and not an evaluation of forest practices. Therefore, disturbance caused by flooding and natural erodible soils can still cause detrimental impacts to a stream as seen in this study and these natural influences should be considered when looking at impacted sites.

4 Conclusions and Recommendations

High failure rates for riparian indicators were the main reason for lower evaluation scores given to the harvested sites compared to the reference sites. Lower reaches had slightly lower failure rates than upper reaches for disturbed ground, LWD supply, and riparian vegetation. A larger average riparian buffer is likely the biggest contributing factor to this difference. While many of the upper sites had been logged to the stream bank, lower sites were rarely subject to riparian harvesting or had a large buffer zone.

None of the upper-basin sites and only four of those in the lower basin scored as properly functioning. Out of the four lower-basin sites, three had large riparian buffers and one was only logged on one side, adding to the inference that buffers are critical. The logistic regression lends support to this suggestion with the identification of harvest date and buffer width as predictor variables for several of the riparian indicators.

While there has been some deliberation over the effective size of a reserve zone for smaller streams, the Riparian Management Area Guidebook (BC Ministry of Forests 1995a) suggests that a 10 m buffer is sufficient to sustain fisheries and wildlife habitats and protect water quality in S4 reaches. A multi-year study in the Prince George region also suggests that a 10 m buffer is required for small streams to maintain an adequate LWD supply and regulate stream function (John Rex. BC Ministry of Forests, Prince George, unpublished results of continuing study). Once streamside vegetation is removed, the open canopy can result in changes to water temperature and a reduction in aquatic food supply, thus impacting fish (Bunnell et al. 2004; Beschta et al. 1987). Riparian vegetation retention is equally important in streams that are not fish-bearing to help maintain hydrologic function, channel conditions and support other species. Amphibians and terrestrial vertebrates can be affected by an open canopy which can cause a drier bank microclimate and habitat fragmentation (Olson et al. 2007; Bunnell et al. 2004). According to field observations and thresholds set out in the RREE, a buffer containing at least 75% of the natural riparian community is suggested to ensure proper functioning of a stream and its riparian area over the long term.

Recommendation #1 – All harvest planning for mountain pine beetle salvage areas should include the retention of sufficient riparian vegetation to help provide for stream channel and aquatic habitat functions and integrity. A 10 m reserve is recommended based on the Riparian Management Area Guidebook and previous studies. Consider a 10 m riparian reserve for S4 streams and those non-fish streams that are a direct tributary to fish-bearing streams. If the retention of highly infested riparian timber during salvage logging poses a windthrow risk, selective harvest methods and machine free zones should be implemented and no more than 25% of the total riparian area harvested.

Several indicators in both the harvested and reference groups likely failed because of high flows. One of the secondary impacts of flooding is the increase in log jams as LWD is washed downstream. In the larger lower-basin reaches, there were no failures for aquatic connectivity while the harvested reaches failed 43% of the time. This may be attributed to the large amount of harvest-related debris observed in the streams.

Recommendation #2 – Avoid depositing woody debris into stream channels during harvest operations. Harvest outside of the reserve zone and fall and yard away from streams to circumvent physical contact with the streambed and banks. When slash and debris are inadvertently deposited, remove only those stems that can be lifted clear without damage to the channel bed or bank. For those that cannot be lifted clear, ensure the stem and limbs do not obstruct stream flow or fish passage.

Fine sediments were seen throughout the watershed in both the harvested and reference sites. Soil maps and field observations indicate that glacial-lacustrine and glacial-fluvial material is fairly consistent with small pockets of colluvial material interspersed throughout the watershed. Both harvested and reference upper-basin sites had comparable failures for fines but the results were variable within each group. Soil erodibility, harvest date, buffer width, channel width and slope were identified by the logistic regression as predictor variables, meaning that in addition to harvesting, site characteristics also influenced the results. The larger ECA and road density of the harvested basins were also probable causes of fine sediment accumulations in the lower reaches.

Recommendation #3 – In sensitive areas where clay, silt and fine sands are abundant and/or steeper slopes prevail, road network design should minimize the number of crossings. To further mitigate the contribution of fine sediments, keep ditchlines short and employ common methods to prevent sediment delivery to streams from road surfaces and ditches. In addition, the riparian reserve zone and the management area should be left unharvested for all sized streams.

Disturbed ground failures were only noted at the harvested sites and could potentially lead to failures for other indicators. Increased runoff and sedimentation due to exposed soil and compacted ground will add more fluvial power and sedimentation to a stream, causing damage to the channel bed and banks. The inclusion of harvest date as an important predictor variable for fines and bare/disturbed ground in the logistic regression signifies recovery over time as re-growth of vegetation becomes established.

Recommendation #4 – In addition to replanting harvested areas in a timely manner, any exposed soil caused by machine disturbance should be planted or seeded with deep-rooted species, and all access roads no longer in use should be deactivated. In addition, the deactivated road surface should be crowned, outsloped, insloped, or cross-ditched depending on the soil type and gradient to prevent any artificial drainage from reaching the natural drainage system. Remove berms from the outside edge where runoff is channelled and, if necessary, recontour and route discharge into a filtration zone before introducing to a stream.

Overall, the sample reaches in basins that experienced more extensive harvest activity and had a moderate or high IWAP hazard ranking scored lower on the RREE than the reference (low hazard) sites. While it was unfortunate that the harvested sites have not fully recovered after 20-30 years, it was constructive to see the RREE results correspond to the IWAP information, which substantiates that this was a useful method to use in planning the field design. In addition to predicting hydrologically sensitive areas, watershed assessment reports contain beneficial land use recommendations such as proposed restrictions and special road construction techniques for specific unstable areas (Beaudry 1997). The recommendations used in this report, published RREEs and existing WAPs should be considered when planning future land use activities.

Recommendation #5 – In addition to conducting a watershed assessment (BC Watershed Assessment Procedure or equivalent analysis) as part of the preliminary stage of harvest activity, previous reports should be consulted. Check Ministry of Forests and Range records for existing watershed, channel, and related assessment information including WAPs and RREEs and implement any recommendations into future land use activities.
http://www.for.gov.bc.ca/hfd/library/lib_pub.htm

5 Summary

This project included the objective of designing best management practices on the results. After researching various publications, we recognize that our recommendations already exist in the form of best management practices in the BC Ministry of Forests Riparian Area Management Guidebook and the Forest Roads Guidebook. Though these BMPs are already in place, this study is valuable because it provides research-based support to the recommended practices, thereby validating them.

Based on our findings and field observations, we did not see a significant impact from harvesting reflected in the stream indicators. Even after the adjustment for natural variation, several of the indicators had similar percent failures between reference and harvested sites, indicating potential recovery of stream function since harvest. Conversely, riparian indicators exhibited a much higher failure rate in harvested areas compared to reference sites. Clearcutting riparian vegetation resulted in an overall average evaluation ranking of functioning at risk to functioning at high risk after a recovery period of 20-30 years. These results suggest much more time is needed to restore conditions to that of an unmanaged riparian forest.

6 Acknowledgements

This project was funded by the Government of Canada through the Mountain Pine Beetle Initiative, a program administered by Natural Resources Canada, Canadian Forest Service. Publication does not necessarily signify that the contents of this report reflect the views or policies of Natural Resources Canada – Canadian Forest Service. Partial funding was also received by the BC Ministry of Environment and the BC Ministry of Forests and Range.

7 Literature Cited

Anderson, N.H.; Sedell, J.R. 1979. Detritus processing by macroinvertebrates in stream ecosystems. Annotated Review of Entomology 24:351-377.

Aumen, N.G.; Hawkins, C.P.; Gregory, S.V. 1990. Influence of woody debris on nutrient retention in catastrophically disturbed streams. Hydrobiology 190:183-191.

Beaudry, P. 1997. Research note: The Bowron River watershed. Prince George Forest Region. Forest Resources and Practices Team. January 1997, Note #PG-09.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resources Research 14:1011-1016.

Beschta, R.L.; Bilby, R.E.; Brown, G.W.; Holtby, L.B.; Hofstra, T.D. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions. Pages 191-232 *in* E.O. Salo and T.W. Cundy (editors). Forestry and Fisheries Interactions. Contribution Number 57. University of Washington. Institute of Forest Resources, Seattle, WA.

Bilby, R.E.; Ward, J.W. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society 118(4):368–378.

B.C. Ministry of Environment. 2007. Fisheries Information Summary System (FISS). http://www.env.gov.bc.ca/fish/fiss/index.html Accessed 28 November 2008.

BC Ministry of Forests. 1995a. Riparian management area guidebook. Province of BC. Victoria. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm. Accessed 28 November 2008.

B.C. Ministry of Forests. 1995b. Watershed assessment procedure guidebook. 1st ed. Forest Practices Branch, Victoria, B.C. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/iwap/iwap-toc.htm Accessed 28 November 2008.

BC Ministry of Forests. 2005. MPB salvage, hydrology recommendations. Recommended operational procedures to address hydrological concerns. http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/stewardship/Hydrological%20Recommendations%20Dec%203%202004.pdf Accessed 28 November 2008.

BC Ministry of Forests. 2007. Biogeoclimatic Ecosystem Classification (BEC) Program. http://www.for.gov.bc.ca/hre/becweb/ Accessed 28 November 2008.

Bunnell, F.L.; Squires, K.A.; Houde, I. 2004. Evaluating effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Mountain Pine Beetle Initiative Working Paper 2004-02. 57 p.

Buttle, J.M.; Creed, I.F.; Pomeroy, J.W. 2000. Advances in Canadian forest hydrology 1995-98. Hydrological Processes 14:1551-1578.

Croke, J.C.; Hairsine, P.B. 2006. Sediment delivery in managed forests: A review. Environmental Reviews 14:59-87.

Haschenburger, J.K., ; Rice, S.P. 2004. Changes in woody debris and bed material texture in a gravel-bed channel. Geomorphology 60:241-267.

Hogan, D.L.; Tschaplinski, P.J.; Chatwin, S. (editors) 1998. Carnation Creek and Queen Charlotte Islands fish/forestry workshop: Applying 20 years of coastal research to management solutions. B.C. Land Management Handbook No. 41. B.C. Ministry of Forests, Research Branch, Victoria, B.C. B.C. 275 p.

Hyatt, T.L.; Waldo, T.Z.; Beechie, T.J. 2004. A watershed scale assessment of riparian forests with implications for restoration. Restoration Ecology 12:175-183.

Mossop, B.; Bradford, M.J. 2004. Importance of large woody debris for juvenile chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada. Canadian Journal of Forest Research 34: 1955-1966.

Nakamura, F.; Swanson, F.J. 1993. Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon. Earth Surface Processes and Landforms 18:43-61.

Natural Resources Canada. Mountain Pine Beetle Program. 2007. http://www.mpb.cfs.nrcan.gc.ca/index_e.html Accessed 28 November 2008.

Nordin, L.J., J.F. Rex, D.A. Maloney and P.J. Tschaplinski. 2008. Standardized Approaches in Effectiveness Monitoring Programs and Regional Relevance: Lessons from the Bowron River Watershed Riparian Evaluation Project. Canadian Journal of Forest Research 38:3139-3150.

Nordin, L. 2008. The Bowron River watershed: a synoptic assessment of stream and riparian condition 20-30 years after salvage logging. Extension Note 86. Ministry of Forests & range Research Branch. 8p.

Olson, D.H.; Anderson, P.D.; Frissell, C.A.; Welsh, H.H.; Bradford, D.F. 2007. Biodiversity management approaches for stream-riparian areas: Perspectives for Pacific Northwest headwater forests, microclimates and amphibians. Forestry Ecology Management 246:81-107.

Roni, P.; Quinn, T.P. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:282-292.

Scherer, R. 2001. Effects of changes in forest cover on streamflow: A literature review. Pages 44-55 *in* D.A.A. Toews and S. Chatwin. Watershed Assessment in the Southern Interior of British Columbia: Workshop Proceedings. 9-10 May, Penticton, British Columbia. B.C. Ministry of Forests, Research Branch.

Taylor, S.W.; Carroll, A.L. 2003. Disturbance, forest age, and mountain pine beetle outbreak dynamics in BC: A historical perspective. Pages 41-51 *in* T.L. Shore, J.E. Brooks and J.E. Stone (editors). Mountain Pine Beetle Symposium: Challenges and Solutions, October 30-31, 2003, Kelowna, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Information Report BC-X-399. 298 p.

Tripp, D.B.; Tschaplinski, P.J.; Bird, S.A.; Hogan, D.L. 2007. Protocol for evaluating the condition of streams and riparian management areas (riparian management routine effectiveness evaluation). Forest and Range Evaluation Program, B.C. Ministry of Forests and Range and B.C. Ministry of Environment, Victoria, B.C.

Wilson, B. 2003. An overview of the mountain pine beetle initiative. Pages 3-9 *in* T.L. Shore, J.E. Brooks, and J.E. Stone (editors). Mountain Pine Beetle Symposium: Challenges and Solutions, October 30-31, 2003, Kelowna, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Information Report BC-X-399. 298 p.

Winkler, R.D.; Spittlehouse, D.L.; Golding, D.L. 2005. Measured differences in snow accumulation and melt among clearcut, juvenile, and mature forests in southern British Columbia. Hydrological Processes 19:51-62.

Wright, K.A.; Sendek, K.H.; Rice, R.M.; Thomas, R.B. 1990. Logging effects on streamflow: Storm runoff at Caspar Creek in northwestern California. Water Resources Research 26:1657-1667.

Contacts:

John Rex or David Maloney
Ministry of Forests and Range,
Northern Interior Forest Region,
5th Floor, 1011 4th Avenue,
Prince George, BC V2L 3H9

John.Rex@gov.bc.ca or David.Maloney@gov.bc.ca

8 Appendices

Appendix 1. Watershed Assessment Procedure Report Card. Taken from the 1995 BC Interior Watershed Assessment Guidebook. Available at:
http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/iwap/iwap-toc.htm
Accessed 28 November 2008.

Impact category	Indicators	Sub-basin name										
Peak flow	1. *peak flow index*											
	2. *road density above H_{60} line* (km/km^2)											
	3. *road density for entire sub-basin* (km/km^2)											
Surface erosion	4. *roads on erodible soil* (km/km^2)											
	5. *roads < 100 m from a stream* (km/km^2)											
	6. *roads on erodible soils < 100 m from a stream* (no./km^2)											
	7. *no. of stream crossings* (no./km^2)											
	8. *road density for entire sub-basin* (km/km^2)											
Riparian buffer	9. *portion of stream logged* (km/km)											
	10. *portion of fish-bearing stream logged* (km/km)											
Mass wasting	11. *no. of landslides* (no./km^2)											
	12. *roads on unstable slopes* (km/km^2)											
	13. *streambanks logged on slopes > 60%* (km/km^2)											
Other land uses	*Crown range use?* (Y/N)											
	All terrain vehicles? (Y/N)											
	Mining? (Y/N)											

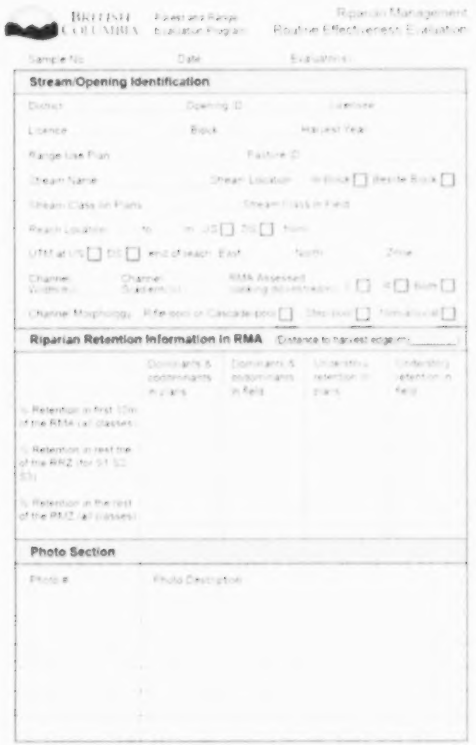
Appendix 2. Riparian Management Areas for British Columbia streams. Taken from the BC Riparian Management Area Guidebook.
Available at: http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/rip-toc.htm
Accessed 28 November 2008.

Riparian class	Average channel width (m)	Reserve zone width (m)	Management zone width (m)	Total RMA width (m)
S1 large rivers	≥100	0	100	100
S1 (except large rivers)	>20	50	20	70
S2	>5≤20	30	20	50
S3	1.5≤5	20	20	40
S4	<1.5	0	30	30
S5	>3	0	30	30
S6	≤3	0	20	20

☐ Fish stream or community watershed

☐ Not fish stream and not in community watershed

Appendix 3. Routine Riparian Effectiveness Evaluation Field Cards.



BRITISH COLUMBIA Forest and Range Evaluation Program — Riparian Management: Routine Effectiveness Evaluation

Sample No. Date Evaluators

Stream/Opening Identification

District Opening ID Licensee

Licence Block Harvest Year

Range Use Plan Pasture ID

Stream Name Stream Location In Block ☐ Beside Block ☐

Stream Class on Plans Stream Class in Field

Reach Location from to In US ☐ DS ☐ from

UTM at US ☐ DS ☐ end of reach East North Zone

Channel Width (m) Channel Gradient (%) RMA Assessed (sloping accumulation) S ☐ N ☐ Both ☐

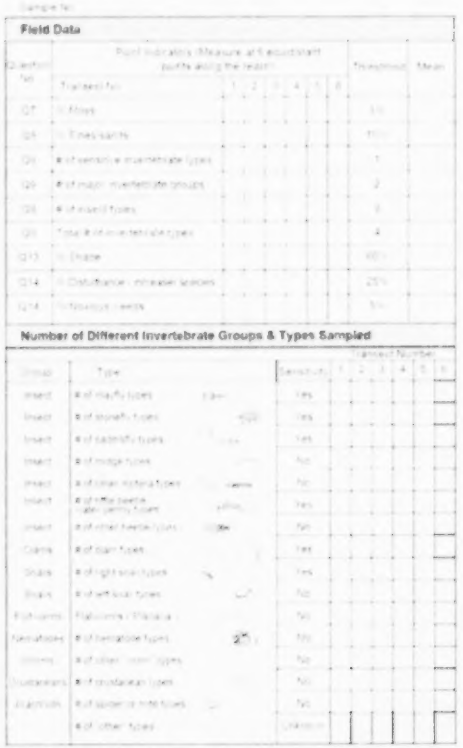
Channel Morphology Riffle-pool or Cascade-pool ☐ Step-pool ☐ Non-alluvial ☐

Riparian Retention Information in RMA Distance to harvest edge (m)

	Dominants & codominants in plans	Dominants & codominants in field	Underst'ry retention in plans	Underst'ry retention in field
a. Retention in first 10m of the RMA (all classes)				
b. Retention in rest the of the RMZ (for S1 S2 S3)				
c. Retention in the rest of the RMZ (all classes)				

Photo Section

Photo #	Photo Description



Sample No.

Field Data

Question No.	Point Indicators (Measure at 5 equidistant points along the reach)	Threshold	Mean
Q6	Transect No.		
Q7	% Rock	15%	
Q8	% Fines/sands	15%	
Q9	# of sensitive invertebrate types	1	
Q10	# of major invertebrate groups	2	
Q11	# of insect types	3	
Q12	Total # of invertebrate types	4	
Q13	% Shade	40%	
Q14	% Disturbance - increase species	25%	
Q14	% Noxious weeds	5%	

Number of Different Invertebrate Groups & Types Sampled

Group	Type	Sensitivity	Transect Number 1	2	3	4	5	6
Insect	# of mayfly types	Yes						
Insect	# of stonefly types	Yes						
Insect	# of caddisfly types	Yes						
Insect	# of midge types	No						
Insect	# of other native types	No						
Insect	# of riffle beetle (adult/larvae) types	Yes						
Insect	# of other beetle types	No						
Clams	# of clam types	Yes						
Snails	# of right-coil types	Yes						
Snails	# of left-coil types	No						
Fish forms	Fish forms / Chordata	No						
Nematodes	# of nematode types	No						
Worms	# of other worm types	No						
Crustaceans	# of crustacean types	No						
Arachnids	# of spiders & mite types	No						
	# of other types	Unknown						

Sample No.

OTHER INDICATORS TO NOTE

Q1 Channel Spanning Steps (For Step-Pool Channels Only): 80% or more of the boulder steps do or do not span the channel. 25% or more do or do not have notch

Q2 Sediment and LWD Storage (For Non-Alluvial Channel Only): Sediment and or LWD do or do not completely fill the channel up to the top of the banks at any point or points together representing more than 5% of the reach length

Q3 Moss Along the Channel Bed (For Non-Alluvial Channels Only): More than 50% of the channel bed length does or does not have some moss on the substrate

Q7 Non-erodible Banks: Banks that are non-erodible on both sides of the stream at the same time are or are not present. Thresholds for stable undercut banks or deeply rooted banks are based on the length of erodible banks present only. Base the percent of undercut bank or deeply rooted bank present on total reach length minus the length of non-erodible bank present. Table

Q13 Main Woody Debris Characteristics: Is the channel... mostly debris-poor, near-natural or logging related, across or parallel, intact or not recently removed or mostly hard, catastrophic floods, or debris torrents?

Q4 Surface Sediment Texture: The texture is homogeneous or heterogeneous

Q4 Steps and Pools (For Step-Pool Channels Only): Cascades lacking steps account for more or less than 25% of the service reach

Q4 Plunge Pool Characteristics (For Step-Pool Channels Only): More than 25% of the steps at stable sites do or do not have a plunge pool as seen at the largest rock in the step. More than one step is or is not completely efficient

Q5 Unconsolidated or Mixed Gravel, i.e. clean bottom structures present or not or not present, no temporary blockages, no dune cutting, no sediment or debris buildup, no threatening quantities of fines, areas not scoured, generally free of quantities of sediments and debris possible

Q8 Fish Cover Types Present include deep water, boulders, undercut banks, cobbly debris, aquatic vegetation, overhanging vegetation

Q8 Fine Sediments: Check if there are any fine or sand sized sediment deposits that "blanket" the stream anywhere or not... whether the substrate is embedded in sand fines or not or whether "quicksand" or "quicksand" is present or not

Q10 Bank Soils are stable or warm, mostly dry, unchanged in pH. Moisture loving plants are present or absent, are or are not in good condition

Q10 Vegetation: All vegetation layers and the structure expected of a healthy unmanaged forest are or are not present (e.g. grass, shrubs, trees, tall shrubs, low shrubs, herbaceous plants, mosses, others)

Q10 Vegetation: Is form normal or not, vigor normal or not, establishment normal or not?

Q10 Browse: Grazing: Heavily browsed shrubs are or are not present. Heavy grazing is or is not present on more than 10% of the available forage

Sample No.

Field Data

Question No.	Continuous indicator. Measure along the total length of the reach.	Thresholds*	Type
Q1	Moderately deep margins (m) - measure all but no overlap		Habitat
Q2	Large bars (m) - measure all but no overlap		Habitat
Q3	Multiple or braided channels (m) - measure all but no overlap		Habitat
Q4	Recently disturbed bank (m) - always measure both sides, but no overlap		Habitat
Q5	Stable undercut bank (m) - always measure both sides, but no overlap		Habitat
Q6	Deep rooted bank (m) - only measure the side(s) affected by the treatment		Habitat
Q7	Disturbed bank and bars (m) - always measure both sides, but no overlap		Habitat
Q8	Number debris accumulations		NA
Q9	Number debris accumulations - on recent debris		Habitat
Q10	Number debris accumulations - on recent debris that span the channel		Habitat
Q11	Pool length (m)		Habitat
Q12	Pool number		Habitat
Q13	Riffle / shallow - number		Habitat
Q14	Dam (man) - number		NA
Q15	Standing trees number		NA
Q16	Bare sand in flat (0m-2m2)		Sand
Q17	Bare soil exposed to rain in flat (0m-2m2)		Sand
Q18	Bare soil hydrologically connected to flat (0m-2m2) - include Q16 bare soil in flat (0m) to decide if threshold is exceeded		Sand
Q19	Disturbed ground in flat (0m-2m2)		Sand
Q20	Disturbed ground hydrologically connected to flat (0m-2m2) - include Q16 disturbed ground in flat (0m) to decide if threshold is exceeded		Sand

*Threshold values depending on of dams, tributaries

Sample No.

Notes, Diagrams

Sample No.

TIPS

Non-Alluvial Channels - in these areas, where the stream gradient is often steeper than alluvial streams, it is usually considered a bank. This means that in many non-alluvial streams there is no bed to measure. The boundary between bank and bed has been given size categories which are typically used to describe materials that are present in the bank or the stream. Some materials may span more than one category, so it is up to the surveyor to decide which category they fall into. Usually, particles are placed in the category that they have the most of. For example, if a particle is 60% gravel and 40% cobble, it would be placed in the gravel category. Because they don't move, these particles are frequently found supporting algae and moss on them in forested areas. Edges of adjacent beds and bars should be used to gain access to adjacent channels. In rugged areas, these may be the only continuous access.

1. Gravel Bars and Multiple Braided Channels - Measure the total length of gravel present with these indicators, but do not count the length more than once for multiple channels.

2. Recently Disturbed Banks, Stable Undercut Banks, and Recently Vegetated Bank Rootheads - For each of these indicators, determine the total length present on both banks even if just one side of the stream area is being assessed. Do not double count the length of channel affected by these indicators. Have the indicators overlap.

3. Deep Rooted Banks - Only measure the side(s) of the riparian treatment(s) being assessed. Assess both sides of the stream are being assessed, record the length of bank on the least amount of deep rooted vegetation. Deep rooted banks are vegetation on trees, shrubs and deep rooted grass species, not forbs, moss or rushes.

4. Fine Sediments - Fine and sand sized sediments include rangeland soil material sediments. Silver diameter.

5. Pools and Riffles - Only measure the length of pools that go from bank to bank. Do not measure pools that go only partially to the middle of riffles or cascades. To find pool riffles or flat / pool cycles of the site, count the boundary between a pool and a riffle or stagnant to the next one. Measure from the center of the diagonal to the next boundary.

Please refer to Figure 5 in the Rapid 3 Protocol

6. Deep pool - "Cave" - To record a "deep" pool, measure pool depth from the deepest part of the pool to the top of the bank (A to B). Then measure the length of the pool. The maximum depth (the point from the deepest part of the riffle to the top of the bank) is 50% of pool length to be at least 1m as deep as the riffle.

Please refer to Figure 6 in the Rapid 3 Protocol

7. Sensitive Invertebrates - Identified, counted, recorded and released. Use the names, Latin Station Key, Identification Key, and pictures in the opening in the right-hand hand to identify the stream and of the small in the bottom.

8. Major Invertebrate Groups - Identify, segment and count, collect gently, earth-worms, leeches, mollusks (e.g. snails and clams), flat worms, nematodes, aquatic and other invertebrate counting. Leave behind.

Weather/sky calculation:

Sample No.

Question 1. Is the channel bed undisturbed? Yes ☐ No ☐

Note: For Questions 1-4, decide what the predominant channel morphology is and then complete the section for that morphology only (i.e. Part A, B or C, not all three).

A) Riffle-pool or cascade-pool channels

a) Less than 50% of the reach length is occupied by active sediment wedges or mid-channel bars ☐ ☐

b) Less than 50% of the reach has active multiple channels and/or braids ☐ ☐

c) More than 50% of the reach has lateral bars ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1

B) Step-pool channels

a) More than 50% of the steps present span the channel ☐ ☐

b) More than 25% of the steps have moss ☐ ☐

c) Less than 25% of the reach has active multiple channels and/or braids ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1

C) Non-alluvial channels

a) Over 25% of the channel bed length has some moss on the substrate ☐ ☐

b) The channel has space for storage of sediments and debris (i.e., sediment and/or LWD) do not fill the channel volume or spill over the banks for any significant distance ☐ ☐

c) Sediments are widely distributed throughout the channel. Sediments are not stored in a few relatively large compartments (e.g., lodged behind an accumulation of immobile rocks or organic debris) ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 1

Stream Channel Morphology - General Characteristics for Small to Medium Size Streams

Channel Type	Typical Gradient (%)	Dominant Type of Stones	Main Pool Types
Riffle-pool	0-3	small gravel and cobbles smoothed by water	lateral, under bank water
Cascade-pool	3-5	medium cobbles and boulders smoothed by water	small plunge pockets
Step-pool	>5	large boulders arranged in lines by stream flow	plunge pools below boulder steps
Non-alluvial	>11	varied, cobbles and boulders come from the bank and are not smoothed or organized by stream flows. Roots often span the channel	plunge pools below boulders, roots or LWD

TIP: When measuring the length of overlapping bars or multiple channel segments, only record the total length of the reach occupied by these features. Don't increase the length by measuring zones of overlap twice.

Sample No.

Question 2. Are the channel banks intact? Yes ☐ No ☐

A) Riffle-pool or cascade-pool channels

a) Less than 15% of the shoreline or streambank on one side of the stream is recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads or harvest and silviculture activities ☐ ☐

b) More than 65% of the bank area immediately adjacent to the channel has deeply rooted vegetation (e.g., deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs) ☐ ☐

c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks ☐ ☐

d) Less than 10% of the reach length has recently upturned (wind throw) root wads along the banks ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 2

B) Step-pool channels

a) Less than 10% of the shoreline or streambank on one side of the stream is recently disturbed by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads or harvest and silviculture activities ☐ ☐

b) More than 75% of the bank has deeply rooted vegetation (e.g. deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs) ☐ ☐

c) More than 50% of the potentially erodible reach length has stable (usually vegetated) undercut banks ☐ ☐

d) Less than 25% of the reach length has recently upturned (wind throw) root wads along the banks ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 2

C) Non-alluvial channels

a) More than 75% of the bank has deeply rooted vegetation (e.g. deep rooting grass species, shrubs, and trees - not moss, shallow rooting grass species, small herbs or forbs) ☐ ☐

b) Less than 10% of the shoreline or streambank on one side of the stream is negatively affected by stream flows, windthrow, infilling, animals (hoof shear, watering sites, crossings), roads or harvest and silviculture activities ☐ ☐

c) Less than 25% of the reach length has recently upturned (wind throw) root wads along the banks ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 2

Please refer to Figures 3 and 4 in the Riparian Protocol. Figure 3 shows a stable vegetated undercut bank. Figure 4 is an example of an unstable, overhanging bank that should not be considered undercut.

Sample No.

Question 3. Are channel LWD processes intact? Yes ☐ No ☐

Note: The words 'recent' and 'recently' refer to the age of the riparian management activity being assessed.

A) Riffle-pool or cascade-pool channel

a) Most woody debris is old and does not appear to have been recently deposited ☐ ☐

b) Fewer than 12 recently formed accumulations of woody debris span the channel ☐ ☐

c) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs) ☐ ☐

d) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant ☐ ☐

e) There is no indication that natural debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods ☐ ☐

If answer "Yes" to 4 or more, mark Yes box in Question 3

B) Step-pool channel

a) Most woody debris is old and does not appear to have been recently deposited ☐ ☐

b) Fewer than 12 recently formed accumulations of woody debris are present in the channel ☐ ☐

c) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs) ☐ ☐

d) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant ☐ ☐

e) There is no indication that natural debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods ☐ ☐

If answer "Yes" to 4 or more, mark Yes box in Question 3

C) Non-alluvial channel

a) Most woody debris is old and does not appear to have been recently deposited ☐ ☐

b) Half or more of all woody debris accumulations lack recent debris (e.g., branches, treetops, bark, small logs and LWD with cut ends, recently crushed or shattered logs) ☐ ☐

c) Woody debris oriented parallel to the channel banks (particularly small logs and limbs with lengths much less than the bankfull channel width) is not abundant ☐ ☐

d) There is no indication that natural woody debris was recently removed from the channel by hand, slides, torrents, or catastrophic floods ☐ ☐

If answer "Yes" to 3 or more, mark Yes box in Question 3

TIP: 'Old' debris is debris that was present before the treatment (i.e., the most recent harvesting or road building). 'Recently deposited' debris means debris that was deposited after road building and harvesting was completed.

TIP: To be considered 'debris in the channel', the debris must actually extend into the channel. Logs that are suspended on the banks above the channel are not included, but any branches associated with the log could be in the channel.

TIP: 'Post harvest / road building-related debris' including branches, is noticeably 'recently deposited debris' if it extends into the channel.

Sample No.

Question 4. Is the channel morphology intact? (Mark NA if the channel is non-alluvial, and therefore lacking a riffle-pool, cascade-pool or step-pool morphology.) Yes ☐ No ☐ NA ☐

A. Riffle-pool or cascade-pool channel:

a. Pools are present along ≥ 25 % of the reach. ☐ ☐

b. Surface sediment texture is heterogeneous and well-sorted, i.e., the number and range of main sediment classes present (fines, sands, gravels, small and large cobbles, small and large boulders) is large and non-randomly distributed. ☐ ☐

c. At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests.) ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 4.

B. Step-pool channel:

a. Plunge pools are frequent (≥ 25 % of steps are associated with a plunge pool with depths similar to the size of the largest rock in the step). Few pools are filled to near the top of the next downstream step. ☐ ☐

b. The channel alternates almost exclusively between steps and pools (i.e., less than 25% of the channel consists of relatively long cascades). ☐ ☐

c. At least two deep pools are present. (A deep pool is a pool with a channel depth twice the average channel depth at riffle crests.) ☐ ☐

If answer "Yes" to 2 or more, mark Yes box in Question 4.

TIP: A stream reach can have aspects of both a cascade-pool and a step-pool morphology. Use the predominant morphology to decide which set (A or B) of indicator statements to use.

TIP: If you cannot decide what the predominant channel morphology is, try completing both sections. More often than not the answers to Question 4 will be the same, in which case it is not necessary to decide what the predominant channel morphology is.

TIP: Steep streams (with gradients between approximately 5-15%) that look like long cascades are probably step-pool streams that are filled in with abundant sediment. Even steeper streams (with gradients much greater than 15%) are probably non-alluvial, especially small streams.

TIP: Only measure the lengths of the main pools present. These are the pools that extend from one side of the wetted channel to the other. Do not include the small pools that are often present behind boulders in riffles or cascades or the small back-water or back eddy pools that might be present along the margins of riffles and cascades.

Sample No.

Question 5. Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris, and sediments? Yes ☐ No ☐ NA

a) Temporary blockages to fish, debris, or sediments because of net accumulations of debris or sediments are absent. ☐ ☐

b) Down cutting in the main channel that has isolates the floodplain from normal flooding or blocks access to tributary streams or off-channel areas is absent. ☐ ☐

c) Build-ups of sediment or debris above or within any crossing structures are absent. ☐ ☐ ☐

d) There is no down cutting present below any crossing structure that blocks fish movements upstream by any age fish at any time. ☐ ☐ ☐

e) On fish bearing streams, all crossing structures are open bottom structures. ☐ ☐ ☐

f) Dewatering over the entire channel width due to excessive fine sediment/burial of sediment is absent. ☐ ☐

g) Off channel or overland flow areas have not been isolated or cut off by roads or levees. ☐ ☐

h) Water in the stream has not been withdrawn or diverted elsewhere. ☐ ☐

If answer "No" to any statements, mark the "No" box for Question 5.

TIP: For Question 5, partial beaver dams should only be considered temporary blockages to fish, sediment and debris if they were constructed after the flow has ceased.

TIP: Down cutting refers to channel incisement, i.e., the vertical movement of the channel bed as it cuts into the floodplain.

Question 6. Does the stream support a good diversity of fish cover attributes? To qualify as cover, each cover attribute should represent at least 1% of the total stream area observed. (Mark NA if the stream is non-fish bearing, i.e., classes S5 or S6). Yes ☐ No ☐ NA ☐

a) Deep pool habitat is available. ☐ ☐

b) Stable, unembedded boulders are present. ☐ ☐

c) Stable rootwads, woody debris, or other organic material that fish can hide in is present. ☐ ☐

d) Stable, deep-rooted, undercut banks are present. ☐ ☐

e) Tall, dense emergent aquatic vegetation is present. ☐ ☐

f) Overhanging vegetation is present within 1 m of the top of the channel (streams) or water surface (wetlands, lakes). ☐ ☐

g) A stable mineral substrate with void spaces for fish to hide in is present. ☐ ☐

If the answer is "Yes" for five or more statements, mark the "Yes" box. Otherwise, mark the "No" box.

TIP: Question 6 is "NA" if the stream is non-fish bearing. Also, if there are no deep pools, there is no deep pool habitat.

Sample No.

Question 7. Does the amount of moss present on the substrates indicate a stable and productive system? Yes ☐ No ☐ NA ☐

a. Moss patches are easily observed from almost any point along the margins, riffles, or shallow pools of the stream. Average coverage on riparian substrates only is 1% or more of the channel bed, from the toe of one bank to the toe of the other bank. ☐ ☐

b. Half or more of the moss present exists in continuous patches or rare patches are generally intact, not embedded with sediments, buried or damaged by scouring. Mark "NA" if no moss is present. ☐ ☐ ☐

c. Moss not scoured, silted, or buried in sediments, generally vigorous, not stressed or dead. Mark "NA" if no moss is present. ☐ ☐ ☐

If the answer is "No" for any statement, mark the "No" box for Question 7. Otherwise, mark the "Yes" box.

Question 8. Has the introduction of fine inorganic sediments been minimized? Yes ☐ No ☐ NA ☐

a. Inorganic, gritty, feeling, fine and sand-sized sediments on the substrate are best described as "thin or patchy." Average coverage is less than 10% with no single area over 30%. ☐ ☐

b. Wetted areas of gravel, sand, or fine silted sediments that a fish can be easily spotted or caught into represent less than 1% of the total wetted area. Mark "NA" if the stream is dry. ☐ ☐ ☐

c. Gravels and cobbles are not embedded or buried in a matrix of sand or finer silted particles. The sides of individual gravel and cobble particles can generally be seen touching each other. ☐ ☐

d. An active age of one invertebrate sensitive to the effects of sedimentation is present at most sample sites. Mark "NA" if the stream is dry. ☐ ☐ ☐

If the answer is "No" to any statement, mark the "No" box for Question 8. Otherwise, mark the "Yes" box.

Question 9. Does the stream support a diversity of aquatic invertebrates? (Mark "NA" if the stream is dry.) Yes ☐ No ☐ NA ☐

a) An average of one sensitive invertebrate (e.g., a caddisfly, stonefly, mayfly, freshwater shrimp, etc.) is present at each sample site. ☐ ☐

b) An average of two different major invertebrate groups (e.g., insects, worms, molluscs, crustaceans, etc.) is present at each sample site. ☐ ☐

c) An average of three recognizably different insects is present at each sample site. ☐ ☐

d) An average of four recognizably different invertebrates is present at each sample site. ☐ ☐

Mark the "Yes" box for Question 9 if two of the statements are "Yes". Otherwise, mark "No".

Sample No.

Question 10. Has the vegetation retained in the RMA been sufficiently protected from windthrow?	Yes	No	NA
a) The incidence of post-treatment windthrow in S1-S3 RRZs or S4-S6 RMZs with WTPs does not exceed 5% of the stems, over and above what occurs naturally in the area. Mark NA and answer 10 b) if there is no reserve zone or management zone with wildlife trees or wildlife tree patches.	☐	☐	☐
b) The incidence of post-treatment windthrow in S4-S6 RMZs that are not part of a WTP does not exceed 10% of the stems, over and above what occurs naturally in the area. Mark NA if there is a reserve zone or wildlife tree patch adjacent to the stream, and answer 10 a).	☐	☐	☐
c) Designated wildlife trees are still standing or if windthrown still functional as wildlife trees (e.g. ablow-ground bear dens). Mark NA if there are no designated wildlife trees.	☐	☐	☐

If the answer is "No" to any statement, mark the "No" box for Question 10. Otherwise, mark the "Yes" box.

Calculating % Windthrow

1) % Old Windthrow = [# Old Windthrown Trees] / [# Standing Trees + # Old Windthrown Trees] X 100

2) % New Windthrow = [# New Windthrown Trees] / [# Standing Trees + # New Windthrown Trees] X 100

To calculate % new windthrow over and above the natural pre-treatment windthrow, subtract (1) from (2).

Question 11. Has the amount of bare erodible ground or soil disturbance in the riparian area been minimized?	Yes	No
a) Total bare erodible ground in the first 10m of the riparian zone is less than 1%.	☐	☐
b) Total bare erodible ground present in the first 10 m of the riparian zone, plus all other bare erodible ground hydrologically linked to the first 10 m of riparian zone, is less than 2%.	☐	☐
c) Total area disturbed by animals or machinery in the first 10m of the riparian zone is less than 10%.	☐	☐
d) Total area disturbed by animals or machinery in the first 10 m of the riparian zone, plus all other disturbed areas hydrologically linked to the first 10 m of riparian zone, is less than 15%.	☐	☐

If the answer is "Yes" for all statements, mark the "Yes" box. Otherwise, mark the "No" box.

TIP: Sediment deposited on the ground from upslope sources is considered bare ground for Question 11, but not if the sediment is deposited due to flooding (i.e. overbank deposits).

Sample No.

Question 12. Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	Yes	No	NA
a) On all streams, non-merchantable conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation were retained to the fullest extent possible within 5 m of the channel.	☐	☐	
b) On S1 to S3 size streams, the first 10 m of the riparian reserve zone is intact, regardless of windthrow, thereby providing for 90 % of the LWD normally supplied to streams, with no additional inputs from upstream or the adjacent hillslopes.	☐	☐	☐
c) On S4 streams where the windthrow hazard was not assessed or where windthrow hazard, as assessed on the Silviculture Prescription is not high, all conifer trees with roots embedded in the bank, and 50% of all other trees, excluding dominant conifers, within 10 m of the stream bank were retained.	☐	☐	☐
d) On S4 streams where the windthrow hazard as assessed on the Silviculture Prescription is high, all conifers > 10 cm DBH were retained within 15 m of the stream bank.	☐	☐	☐
e) On valley bottom S5 streams, all gravel bars and a minimum 50 % of dominant and codominant conifer stems within 30 m of the stream bank were retained.	☐	☐	☐
f) On non-valley, LWD-dependent S5 streams, all leaners within 10 m of the channel and all conifer stems > 10 cm DBH within 5 m of the stream bank were retained.	☐	☐	☐
g) On LWD-dependent S6 streams, or S6 that flow directly into fish-bearing waters, at least 10 trees > 10 cm DBH per 100 m of stream bank were retained within 5 m of the stream bank.	☐	☐	☐

Mark the "Yes" box for Question 12 if there are any "Yes" answers. Otherwise, mark the "Yes" box.

TIP: All streams require an answer to indicator statement 12 (a). At most, only one other indicator statement will be applicable.

TIP: Stream crossing right-of-ways should not be considered a factor for this question unless the right-of-ways represent more than 25% of the riparian habitat.

Question 13. Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	Yes	No
a) With the exception of active roads at stream crossings, bare ground directly exposed to sun is less than 1% of the riparian habitat in plan view.	☐	☐
b) Shade, the average amount of sky not visible due to vegetation, averages more than 80% as estimated visually for any two of the east, south, and west aspects at 50 cm above the humus/soil or as estimated with a "full" angular canopy densiometer.	☐	☐
c) Moisture loving macrophytes, mosses, ferns, or other bryophytes are present and in vigorous condition with no indication of stress due to sunburn, drought or desiccation.	☐	☐
d) Soil in the riparian habitat is moist or cool to the touch.	☐	☐

Mark the "Yes" box for Question 13 if 3 or more answers are "Yes". Otherwise, mark the "No" box.

TIP: All four indicator statements should be answered. This question needs two or more "No" answers to the indicator statements before the Question can be answered "No".

Sample No.

Question 14. Have the number of disturbance-increaser species or noxious weeds present been limited to a satisfactory level?	Yes	No
a) Disturbance-increaser plants (domestic grasses, dandelions, pineapple weed, hairy cats, etc.) occupy less than 2% of total area in the first 10m of the riparian zone.	☐	☐
b) Noxious weeds (Canada thistle, scentless chamomile, orange hawkweed, etc.) occupy less than 5% of total area in the first 10m of the riparian area.	☐	☐

Mark the "Yes" box for Question 14 if all statements are "Yes". Otherwise, mark "No".

TIP: To estimate coverage by disturbance-increaser plants or weeds at a sample site, try estimating the percentage of a 10m long line transect that is occupied by these plants. Start the line transects at the edge of the stream and go 10m at right angles to the main axis of the stream reach.

Question 15. Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of other healthy unmanaged riparian plant communities in the area?	Yes	No
a) The major vegetation layers expected of healthy unmanaged riparian plant communities in the area (e.g. snags, tall trees, tall shrubs, low shrubs, herbaceous plants, mosses, and lichens) are present over more than 75% of the stream reach.	☐	☐
b) The dominant species in the tree and shrub layers generally exhibit high vigour, normal growth form, and good recruitment of seedlings or saplings. Mark "No" if more than 25% of the specimens in these layers are stressed, dying, dead, burned, mushroomed, windthrown, or harvested. Mark "No" if there is also no recruitment.	☐	☐
c) Heavy browse is absent on a preferred browse species in the shrub layer. Heavy browse on a plant is browse down to second year growth over most (>50%) of the branches of the plant.	☐	☐
d) Heavy grazing occupies <10% of the available grazing area. Heavy grazing is defined as less than the recommended target stubble height for the dominant forage species present.	☐	☐

Mark the "Yes" box for Question 15 if 3 or more answers are "Yes". Otherwise, mark the "No" box.

TIP: All four statements can always be answered "Yes" or "No". There are no NA statements.

TIP: If more than 25% of the first 10m of the riparian area is logged, then 15 a) and 15 b) should be marked "No". This means that for most S4 streams and many S4 streams that are logged to the stream edge, the answer to Question 15 will automatically be "No".

TIP: A preferred browse species may be altogether absent if browsing is intense or prolonged. Their presence may be restricted to inaccessible sites. Huckleberry plants in many locations on the Queen Charlotte Islands/Haida Gwaii, for example, are frequently restricted to the tops of high stumps or other inaccessible sites out of reach of the local deer.

Please refer to Figure 12 in the Riparian Protocol for a description of heavy browse

Sample No.

Summary

Question		Yes	No	NA
Question 1	Is the channel bed undisturbed?	☐	☐	
Question 2	Are the channel banks intact?	☐	☐	
Question 3	Are channel voids, debris processes intact?	☐	☐	
Question 4	Is the channel morphology intact?	☐	☐	☐
Question 5	Are all aspects of the aquatic habitat sufficiently connected to allow for normal, unimpeded movements of fish, organic debris and sediments?	☐	☐	
Question 6	Does the stream support a good diversity of fish cover attributes?	☐	☐	☐
Question 7	Does the amount of moss present on the substrates indicate a stable and productive system?	☐	☐	
Question 8	Has the introduction of fine sediments been minimized?	☐	☐	
Question 9	Does the stream support a diverse, of aquatic invertebrates?	☐	☐	☐
Question 10	Has the vegetation retained in the RMA been sufficiently protected from windthrow?	☐	☐	
Question 11	Has the amount of bare ground or soil disturbance in the riparian area been minimized?	☐	☐	
Question 12	Has sufficient vegetation been retained to maintain an adequate root network or LWD supply?	☐	☐	
Question 13	Has sufficient vegetation been retained to provide shade and reduce bank microclimate change?	☐	☐	
Question 14	Have the number of disturbance-increaser plants or noxious weeds present been limited to a satisfactory level?	☐	☐	
Question 15	Is the riparian vegetation within the first 10m from the edge of the stream generally characteristic of other healthy unmanaged riparian plant communities in the area?	☐	☐	

No. of Yes answers _____ + No. of No' answers _____ + No. of NA answers _____ = Total No. of answers _____

Conclusion on Functioning Condition (check one):

- ☐ Properly Functioning (0-2 No's)
- ☐ Properly Functioning but at Risk (3-4 No's)
- ☐ Properly Functioning but at High Risk (5-6 No's)
- ☐ Not Properly Functioning (>6 No's)

List the questions that had a 'No' answer below, and check what you believe was the main reason for the problem. A 'No' answer due to natural causes would include any natural event such as insects, fires, floods, slides, diseases etc. that were clearly unrelated to man's activities in the stream or adjacent riparian area. Check Logging, Cattle, Roads or Other Manmade as a cause if these factors directly affected the stream or riparian area assessed in this evaluation. Check Upstream Factors if the No answer was the result of some event or condition that occurred upstream, regardless if it was manmade or natural.

No answer questions	Cause of 'No' Answers					
	Logging	Cattle	Roads	Other Manmade	Natural Factors	Upstream Factors
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐

Sample No.

Checklist of Specific Impacts for All "NO" Answers Combined

	Stream Impacts that Apply	
	Within Stream Reach	Above Stream Reach
Logging Related Impacts		
Falling and yarding	☐	☐
Machine disturbance during harvest	☐	☐
Machine disturbance during site preparation	☐	☐
Windthrow	☐	☐
Low retention	☐	☐
Old logging	☐	☐
Surface erosion	☐	☐
Terracing	☐	☐
Water courses diverted	☐	☐
Roads, Crossings		
Running surface grading into stream	☐	☐
Ditches grading into stream	☐	☐
Fill or soil wedge eroding into stream	☐	☐
Road bank failing/collapsing	☐	☐
Culvert eroding/undermined	☐	☐
Ditch blocks inadequate	☐	☐
Cross drains inadequate	☐	☐
Sediment trap inadequate	☐	☐
Berms/cuts trap water on road	☐	☐
Crossing rutted, fines into stream	☐	☐
Water courses diverted	☐	☐
Crossing eroding too small	☐	☐
Crossing misaligned	☐	☐
Crossing not open bottomed	☐	☐
Culvert inlet too high	☐	☐
Culvert damaged	☐	☐
Culvert plugged	☐	☐
Animal Disturbance		
Excessive grazing/browsing (cattle)	☐	☐
Excessive grazing/browsing (other ungulates)	☐	☐
Excessive grazing/browsing (beavers)	☐	☐
Trampling (cattle)	☐	☐
Trampling (other animals)	☐	☐
Stream dammed (beavers)	☐	☐
Excessive manure	☐	☐
Natural Impacts		
High natural background sediment levels	☐	☐
Organic stream loss	☐	☐
Fire	☐	☐
Beetle kill	☐	☐
Other diseases, epidemics	☐	☐
Wind	☐	☐
Slides	☐	☐
Torrents	☐	☐
Floods	☐	☐
Unknown	☐	☐
Other Impacts (List)	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

Sample No.

Final Comments

Does the conclusion on functioning condition generally agree with your personal opinion on the functioning condition of this stream reach? If not, why not?

Describe more specifically what the reasons were for the 'No' answers.

All 'No' answers are not weighted equally. Were any specific problems identified that affected the assessment more than others?

Have you marked the stream reach assessed on a map or aerial photo that can be legally photocopied?

Does the wave strip appear as indicated in plans or on plan maps?

Do you have any recommendations for improving the Riparian Effectiveness Routine Evaluation Checklist or Protocol?

Appendix 4. Sub-basin details for cumulative effects in lower sites. RREE scores: PF = Properly functioning, FR = Functioning but at risk, FHR = Functioning but at high risk, NPF = Not properly functioning.

Harvested Sub-Basins	Riparian Hazard Ranking	Basin Area (km2)	Total Road Length (km)	Road density	Total Stream Length (km)	Stream density	ECA	Lower-basin RREE score
A	High	17.49	40.73	2.33	61.69	3.53	51.3	NPF
C	High	11.26	9.07	0.81	48.80	4.33	30.1	NPF
Craze	High	12.47	17.61	1.41	23.43	1.88	44.0	FHR
D	High	55.82	78.88	1.41	216.76	3.88	34.4	FR
18-Mile	High	46.71	144.74	3.10	156.67	3.35	55.0	FHR
14-Mile	Moderate	32.99	57.91	1.76	82.85	2.51	30.0	FHR
G	High	32.73	64.86	1.98	102.93	3.14	12.6	NPF
Grizzly	Moderate	39.25	23.03	0.59	127.75	3.25	12.8	PF
H	High	17.39	29.12	1.68	45.17	2.60	5.8	FR
H3 Creek	Moderate	53.95	57.77	1.07	127.61	2.37	18.5	FR
Haggen	Moderate	257.86	345.34	1.34	1002.31	3.89	24.0	PF
Hah	High	24.14	16.45	0.68	119.48	4.95	12.1	NPF
Indian Point	High	249.77	378.46	1.52	1169.92	4.68	29.0	FR
Ketchum	High	123.53	250.20	2.03	410.26	3.32	42.0	NPF
Lower Bowron	High	252.04	417.35	1.66	1025.70	4.07	28.5	NPF
McKenna	Moderate	22.17	36.70	1.66	96.48	4.35	26.0	FHR
Middle Bowron	High	201.45	458.14	2.27	751.51	3.73	N/A	FR
Pinkerton	High	44.48	85.80	1.93	134.88	3.03	63.0	NPF
Purden	High	66.80	116.02	1.74	196.35	2.94	15.6	FR
Saw	High	14.11	32.43	2.30	60.34	4.28	62.0	NPF
Spruce	High	56.81	93.87	1.65	190.13	3.35	27.8	FR
Taspai	High	66.00	122.09	1.85	251.53	3.81	14.8	FR
10-Mile	High	12.83	20.34	1.59	38.96	3.04	34.0	FHR

Towkuh	High	37.82	83.41	2.21	85.83	2.27	52.0	PF
Tsus-Fly	High	124.40	175.54	1.41	476.46	3.83	33.6	PF
Unnamed A	High	26.93	90.68	3.37	82.06	3.05	41.7	FHR
Upper Bowron	Moderate	597.46	533.81	0.89	2429.05	4.07	N/A	FR
Wendle	High	120.52	162.56	1.35	409.20	3.40	32.0	FHR
AVERAGE		**91.23**	**138.40**	**1.73**	**345.51**	**3.47**	**32.7**	
Reference Sub-Basins								
Control 1 (Lower site)	Low	49.57	25.72	0.52	143.46	2.89	6.4	PF
Control 2 (Upper site)	Low	*	*	*	*	*		
Control 3 (Upper site)	Low	*	*	*	*	*		
Control 4 (Upper site)	Low	*	*	*	*	*		
Control 5 (Lower site)	Low	27.65	20.07	0.73	60.89	2.20	25.0	PF
Control 6 (Upper site)	Low	*	*	*	*	*		
Control 7 (Upper site)	Low	*	*	*	*	*		
Control 8 (Upper site)	Low	*	*	*	*	*		
Control 9 (Lower site)	Low	66.90	108.89	1.63	326.80	4.88	12.0	FR
Control 10 (Upper site)	Low	*	*	*	*	*		
Control 11 (Upper site)	Low	*	*	*	*	*		
AVERAGE		**48.04**	**51.56**	**0.96**	**177.05**	**3.33**	**14.4**	

* Data not applicable as sub-basin information was only used to consider cumulative effects as represented in lower-basin sites.

Contact:

For more information on the Canadian Forest Service, visit our web site at:
cfs.nrcan.gc.ca

or contact the Pacific Forestry Centre
506 West Burnside Road
Victoria, BC V8Z 1M5
Tel: (250) 363-0600 Fax: (250) 363-0775
cfs.nrcan.gc.ca/regions/pfc

To order publications on-line, visit the Canadian Forest Service Bookstore at:
bookstore.cfs.nrcan.gc.ca

OP# 9825